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LIFE AND ITS MAINTENANCE

A Symposium on Biological Problems of the Day

BLACKIE AND SON LIMITED 50 Old Bailey LONDON : GLASGOW & BOMBAY
1919

PREFACE

The subject-matter of this volume was delivered in the form of public lectures at University College, London, by the several authors, during the first half of 1918. Though the majority of the subjects included appear in the form of more or less acute war problems, there are few of them that do not possess at least as great a value in relation to the enjoyment of peace. Most problems need a crisis before they attract serious attention, and it is just this service which the war has rendered. Our problems are really peace-time problems standing out in relief against the background of the war.

Thus, so long as population continues to expand indefinitely and the yield of grain is limited by the area of the earth's surface susceptible to the cultivation of cereals, no one will have the audacity to assert that the determination of the ultimate food and energy resources of the wheat grain is a mere episode of war.

Then take the beautiful work on the vitamines called forth by the appearance of "deficiency" diseases in several theatres of the war. This is probably little more than the starting-point of an enquiry into these mysterious growth factors, the right understanding of

which may well prove to be of supreme importance for the welfare, and, it may be, the advancement of the human race.

If there is a peaceful future for aviation, as so many suppose, the physical and mental tests devised for the selection of war pilots in Colonel Flack's lecture must be the foundation on which we shall build in organizing the personnel of a great new industry of communications.

To mention but one more case. In the field of peaceful industry what results are likely to be of greater utility than the "efficiency and fatigue" data drawn from the munition factories? And what conditions could have been more favourable for their collection than those provided where vast quantities of shells, cartridges, and other engines of war were being produced?

The collection as a whole, incomplete as it necessarily is, seems to show that much of the "war work" of biology will have its peaceful application. The "sword" which the biologist wields in war becomes, automatically, a "ploughshare" with the dawn of peace.

F. W. O.

CONTENTS

BIOLOGICAL PROBLEMS

THE PROBLEM OF FOOD

A notable proportion of the lectures of which the present series consists is occupied with the food question in various aspects. Since it has fallen to my lot to commence the course, it seemed that the most profitable way to occupy the time available was to direct attention to the fundamental aspect of the subject, so that the meaning and significance of the problems dealt with in succeeding lectures should not be missed through failure to understand the expressions made use of.

Thus the present lecture is not intended to deal primarily with food economy. I propose to take as texts certain words and expressions in common use, and to try to explain their meaning. A few remarks will be found at the close of my lecture more directly dealing with the practical aspects of the problem.

The expressions referred to are:

Proteins.
Carbohydrates.
Accessory Factors ("Vitamines").
Calorie.
"Heat-giving" foods.
"Flesh-forming" foods.

We shall find that the last two are misleading expressions, and should be given up altogether. In

the course of the exposition we shall have occasion to consider all that is necessary to the due understanding of all the problems that are likely to meet us subsequently, although naturally in their main aspects only.

Proteins.—When we grow we produce new body substance. When this is subjected to chemical analysis, what do we find that it contains? There are the elements carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus in organic combination, together with certain inorganic salts.

As regards the salts, we do not require to give special attention to them, because they are present in all natural articles of diet, while sulphur and phosphorus are also present, in the comparatively small amounts required, in the sources of nitrogen used. The case is different with the other four elements. We must have not less than some definite and fairly large amount in order to live and work.

Let us direct our attention to nitrogen in the first place. Although this gas is present in the atmosphere in large quantities, animals cannot make use of it in this form, although some plants can do so. For our use it must be already combined with carbon, hydrogen, and oxygen in some form, and the simplest form actually found to serve is that of the amino-acids, which may be regarded roughly as simple organic acids to which is linked the residue of an ammonia group. But although these in the pure state have been shown to be able to serve as nitrogen food, the actual source from which we obtain them, on account of its convenience, is by the digestion of what are known as *proteins*. These consist of a number of amino-acids combined together. The action of the digestive enzymes is to split the proteins up into their constituent amino-acids.

Proteins, then, being the food materials from which

we obtain our nitrogen-supply, we see why a certain daily requirement of these substances is put down in diet tables. Other kinds of food-stuffs contain no nitrogen, and since this element is one of the constituents of our tissues, it is clear that it must be supplied if new tissue is to be made. Familiar examples of proteins are: the lean of meat, white of egg, plasmon from milk, the vegetable proteins in wheat and beans.

But, it may be said, how does this requirement for growth apply to the adult organism, which has ceased to produce new substance? The answer is that the living cell machinery wears away with use, just like other machinery, and nitrogen is one of the elements that is lost, so that it is wanted to replace the loss. So far as we can make out, however, this loss of nitrogen due to wear and tear is not great, and, in theory, the protein required to replace it is correspondingly small. It is indeed remarkable that the actual waste of muscle substance by wear and tear in activity, instead of being more obvious than that of other cell mechanisms, as would be expected, is so small that no increase of nitrogen excretion can be detected, except under such excessive exertion as to become pathological. But here we come across one of the most disputed problems of nutrition, namely, whether it may be advantageous for other reasons to consume more protein than the minimal amount. This question will be touched upon briefly below. Here I may remark that a person in ill health or with bad digestion may probably be able to do better if a large proportion of his diet be made up of protein, not because of greater wear and tear, but on account of the greater ease with which such individuals can make use of protein for the other great purpose of food, namely, the supply of energy, to which we next turn our attention.

Before doing so, a word may be said as to the relative value of animal and vegetable protein. There is no difference. Especially should it be kept in mind that there is no special virtue in butcher's meat. At one time it was thought that vegetable proteins were less digestible. While this may be true for those in certain nuts, the work done in the laboratory of Professor Hopkins at Cambridge, of which an account will be found in the second lecture of this series, shows that the protein in the present "war-bread" is practically utilized in full.

Carbohydrates. — Familiar instances of carbohydrates are starch and sugar. Potatoes consist in large proportion of the former.

In chemical composition they may be regarded as being formed of carbon and water in equal proportions, but differing as to the total number of atoms in their molecules. Since they contain no nitrogen, they cannot serve for growth or for replacement of wear and tear. What then is their use? A similar question applies to fat, the third constituent given in diet tables. We are thus led to a discussion of the meaning of the word "calorie", which is now familiar to everyone as expressing the value of a diet in a particular aspect. So much sugar, for instance, is said to be equivalent to so many "calories".

Calorie.—Perhaps the most striking characteristic of living beings is their perpetual change. Now changes, as we all know, cannot be brought about without work being done, both in the physical and the social spheres. In the language of science, the capacity of doing work is called "energy", and what is important for our present purpose is that the name is used in no metaphorical manner, but for something that can be measured, so that different amounts of energy can be exactly compared. Probably why

there is difficulty in looking upon energy as a real thing is that it cannot be seen and handled as matter is. But one of the most significant and fundamental discoveries of modern science is that there is no loss and no creation of energy, although one form of it can be converted into a corresponding amount of another form. Of these various forms we may mention heat, electricity, motion, energy of chemical change, and so on. The most generally known case in which we actually pay for units of energy as such is that of the electrical energy which we use for heat and light. The facts described above will be recognized by many readers as the *first law of energetics*.

Since, then, any form of energy can be converted into any other, it is convenient to express them all, for the purposes of measurement, in the same unit. And, since all forms can be easily converted into heat, this is chosen. The unit of heat energy is called "calorie". One calorie is the amount of heat required to raise the temperature of 1 kilogram of water by 1° C.

In this process of conversion of one form of energy into another, we come across the *second law of energetics*. Although we can convert any other form of energy completely into heat, we find that the reverse process cannot be completely effected: there is always some heat left unchanged. The proportion is given us by the law mentioned. The fact itself is doubtless connected with the circumstance that we are dealing with heat energy a long way above its zero state.

When we have done work, then, we have lost energy, and, in order to be able to do further work, we must be supplied with more energy. Whence do we get this? It is in the following way: The materials we take as food contain chemical energy which can be converted into other forms—heat, muscular motion, and so on—when they are combined with oxygen, or

burned up, as we say. This combustion is effected by living organisms, and the results, both in the chemical nature of the products and in the amount of energy obtained, are identical with what would have been the case if the food had been burned under a steam boiler. Without oxygen, therefore, we could obtain no energy.

All three classes of food—fat, carbohydrate, and protein—are used for this purpose. Carbohydrate and protein, weight for weight, are equivalent; fat is of higher value in proportion to its weight. The fact that protein contains nitrogen is of no importance in this respect. By far the largest part of our food is needed for the purpose of supplying energy. We should notice that the precise chemical constitution of the food does not matter. The fact is very striking in the case of certain micro-organisms, which are able to burn paraffin, methane, or hydrogen as food for energy purposes. We may compare the structure of living cells to the mechanism of a petrol motor. Work is done by the motor by making use of the energy afforded by the combustion of the fuel with oxygen from the air. The fuel enters in no way into the chemical composition of the motor, and may be either petrol, benzene, alcohol, or other volatile combustible liquid, or even gas. Iron is useless.

To give an aspect of reality to this energy value of food, samples of various food-stuffs, each of 100 calories, have the following weights:—

Casein or egg white (pure proteins) ...	24.5 grm.
Fat	13.5 ,,
Cane-sugar (carbohydrate)	24.5 ,,
Meat	46 ,,
Bread	37.5 ,,
Oatmeal	28 ,,
Milk	145 ,,
Beer	1300 ,,

For a man weighing 70 kilograms (11 stones) the following table indicates the daily energy requirement in calories:—

Basal, in sleep	1700	1 calorie per kilogram per hour
Basal, awake, but lying at rest ...	2100	
Sedentary occupation	2500	
Light work	3000	
Moderate work	3500	
Heavy work	4000 and upwards to 9000 in special cases	

Since the basal consumption is always present, for the work of the heart, respiration, and maintenance of temperature, and is proportional to the weight of the individual, while the energy consumed for an equal amount of external work is the same whatever the weight, within wide limits, it follows, as Lusk has pointed out, that workers of small weight, other things equal, are more economical machines than those of heavy weight.

The American Commission for Relief in Belgium arrived at a minimal supply of 2000 calories, to be supplemented by each person according to opportunity. The table shows that 2000 is just about the bare amount required to keep body and soul together, so that when failure of transport reduced the supply below this value, as happened in Lille, the death rate immediately began to rise.

The composition of a normal diet for moderate work is generally taken to be:

Protein	100 grm.	= 400	calories.
Fat	100 "	= 900	"
Carbohydrate ...	500 "	= 2000	"
Total		3300	"

If more be taken, it is merely wasted, or laid on as fat. We sometimes hear of a "fine, healthy appe-

tite", and it appears to be thought that the more one eats the better. The pig is more useful, because he stores much of the food he consumes for our future use.

One hundred grammes of protein is certainly a liberal allowance, and could probably be reduced without harm if replaced by an equivalent calorie value in carbohydrate or fat. In point of fact, natural articles of diet always contain sufficient protein if consumed in requisite amount to give the necessary energy value. For this reason I have, in another place, altered the well-known proverb so as to apply it to the food problem—"Take care of the calories, the protein will take care of itself".

A few words are desirable in respect of fats. Since both fats and carbohydrates are used for the same purpose of supplying energy, it would be natural to ask, Why do we take both? We know, indeed, that fat can be made out of carbohydrate by the organism, and yet, if fats are withheld, there is an undoubted craving for them. Apart from the difficulty of making palatable dishes without the use of fat, there seems to be evidence that it fulfils some important physiological function. But exactly what this is lies at present in obscurity.

"Flesh-formers."—This is a misleading expression and should not be used. It is usually applied to proteins, but it suggests properties that do not exist. Whatever food be taken it does not of itself cause increased growth of muscle. This growth only results from increased use. For muscular work, the food consumed by preference is carbohydrate. Although protein can be used for energy purposes, it is wasteful to do so. There is evidence also that it may be taken in excess. But any pathological results are not due to increased uric acid production. No evidence has

been brought to show that it is a toxic substance, notwithstanding the nonsense published in certain advertisements.

"Heat-giving" Food.—This name is also used in consequence of a misunderstanding of fundamental facts. Properly speaking, it is applicable to all kinds of food, and is equivalent to energy-giving. The confusion is due to the failure to realize that heat is one of the forms of energy, which are mutually convertible. It is incorrect to speak of "heat *and* energy" as is often done. If a food is capable of affording heat, it is also capable of giving the other kinds of energy also, including that of muscular work. Sugar is sometimes called a heat-giving substance, whereas it is the typical source of energy for muscular contraction. If any food is to be called specially heat-giving, alcohol, according to E. Mellanby's investigations, might perhaps be more appropriately called by this name. Protein, in the particular aspect to be referred to below, might also be included.

Before we pass to this latter point, a word may be said about **Clothing.** Part of our food is spent in keeping up our temperature, mainly as a by-product of muscular work, and especially in cold weather. It is clear, therefore, that the less heat is lost to the outside the less food is needed. Hence a certain economy is effected by warm clothing, and, it may be added, by warming the house.

It is necessary to be cautious in making definite assertions as to any special value of protein food. Some hold that a full protein diet ensures greater resistance to infection. I confess that I have been unable to find any satisfactory evidence that this is the case. Dr. Carter, of Birmingham, in a careful investigation, found no evidence that the incidence of

tuberculosis had any relation to the amount of protein taken. It was clearly related to a low calorie value, and especially to absence of a due proportion of fat.

The question of the so-called "specific dynamic action" of protein is a difficult one. The fact to which this imposing name is given is this. Suppose that the energy given off by an individual is being measured by conversion into heat, and that a known calorie value of fat or carbohydrate is taken and the extra energy output determined. It is found to be equivalent to that of the food taken. This is not so with protein. In this case *more* energy is given out than corresponds to that of the food taken; the chemical processes of the cells have been stimulated to greater activity, and the protein taken has brought about the combustion of other material in addition to that of itself. There is, as yet, some dispute as to whether this is of real advantage to the organism or not. There are two statements with respect to it that make it difficult to believe that it is other than wasteful. It is produced at a particular time after the ingestion of protein, whether wanted at that time or not. And, secondly, it is said to show itself only as heat. Hence my remark above as to protein being in some circumstances a heat-giving food. At the same time the meaning of this statement is not quite clear. Presumably it is that the energy produced by the extra combustion is given off when not required for other purposes, and is therefore wasted in the form of heat. In other words, it must be got rid of somehow. But, of course, if the body is burning up material to keep up its temperature in cold weather the extra heat is not wasted, since it takes the place of other oxidations.

We may remember that in the process of utilization of protein for energy purposes the nitrogenous part is

split off and excreted, while the non-nitrogenous part is oxidized like carbohydrate or fat. It is possible, however, that this latter part may be more easily or more economically oxidized than the more complex carbohydrate or fat. The recent observations of Anderson and Lusk show that protein has no special value in this respect. The amount of energy value required by a dog to do a particular piece of work was the same, whether derived from its own store or from a diet of carbohydrate or of protein, namely, 0.580 kilogrammetre per kilogram of body weight transported 1 metre. It was, perhaps, rather less in the case of carbohydrate. But what is of interest in the present connection is that when protein was used the extra amount of energy due to its "specific dynamic action" was given off *in addition* to that utilized as work; hence playing no part. In other words, when the work was done at the expenditure of protein, the body lost more energy than when the same work was done at the expense of carbohydrate. It is difficult to avoid the conclusion that there was waste.

On the whole, the "specific dynamic action" appears to be merely an incidental occurrence in the mode of utilization of protein, of doubtful, if any, benefit. But there still remains something to be cleared up.

Accessory Factors or "Vitamines".—It is now well known that the presence of some substances in addition to the ordinary fat, carbohydrate, and protein is necessary in order that a diet may be adequate for growth, and also in order that the appearance of certain diseases may be avoided. For this reason these particular diseases are called "deficiency diseases".

Although Captain Cook found out that scurvy could be prevented by taking fresh fruit and vegetables, the chemical nature of these "accessory factors" is still

unknown. It is true that the name "vitamines" was introduced by Casimir Funk a few years ago, on the mistaken belief that he had discovered the chemical nature of the factor necessary to prevent beriberi. The chemical implication of the name is misleading, since it has turned out that, so far from these substances being amines, they do not always even contain nitrogen at all. It would be better to avoid the use of the term altogether, but, owing to the fact that no satisfactory short name has been proposed, "vitamine" has come into rather general use, regrettable as it may be.

The subject is dealt with in a special lecture of this series, so that very few words will suffice in this place.

Most natural articles of food contain some of them, although in varying amounts. Fresh fruit and vegetables are the richest source, especially of the anti-scorbutic factor. They are destroyed by prolonged heating and by certain preservative methods. Alkali makes them more vulnerable.

They appear to be of several kinds, but may be divided into two main groups, as M'Collum has shown. Thus, rats fed on polished rice alone will not grow, nor if butter be added, nor again if wheat germ alone is added. But it is only necessary to add a minute quantity of both together to make polished rice perfectly adequate. The factor in butter is representative of a group soluble in fats, hence called "Fat-soluble A factor". That in wheat germ is one of the group known as "Water-soluble B factor".

Wheat germ or any dried seed is insufficient to prevent scurvy. The factor develops only on germination, as shown by Dr. Chick and Miss Hume.

Economy in Diet.—I may conclude with a few remarks on the question that concerns us so vitally at the present time. That care and economy are always

desirable may be taken for granted; they are now, unfortunately, a necessity.

While accepting this to be the case, I would venture to appeal to the authorities to be perfectly open, and to let us know the whole truth of the matter. Vague statements do not convince, and are sometimes contradictory. People are not impressed by being told that a controller "views the situation with alarm", unless they know how much is required to alarm that particular gentleman. It appears that alarm is frequently founded upon calculations of loss by submarine attack, on the assumption that it will continue to proceed *at the same rate* as the present. If the curve of destruction be examined, a glance will show that it has steadily declined, although in a somewhat irregular fashion.

We cannot shut our eyes to the fact that enormous quantities of wheat, jam, meat, and other things come to us from overseas for the supply of the army. If we were told that we in England must be satisfied with less than usual in order that the army should be well fed, no one would make any protest. There can be no question that the astonishing freedom from disease is, in great part, due to the good food supplied abundantly to the troops. One might perhaps be inclined to be doubtful whether the meat ration might not be somewhat diminished in favour of more carbohydrate. But I am aware that this is a rather contentious subject.

It is universally agreed that the present is a very critical period in the progress of the war, and the question may very well be argued whether it would not be better, in the interests of national efficiency all round, to postpone any possibility of underfeeding until absolutely necessary, leaving the future to take care of itself.

No amount of contempt for the data of science can get over the fact that no work can be obtained without its equivalent energy value in food. Very few of us could be allowed to lie in bed doing nothing.

But the problem arises as to how much is really necessary. We have seen that 2000 calories may be regarded as the absolute minimum for a grown man doing no external work. And that 2500 calories suffices for what are called sedentary occupations. But, according to the careful records obtained by Hopkins and Wood, an average middle-class family before the war consumed about 4400 calories per person. This seems undoubtedly to be unnecessarily great. On the other hand, the diet proposed by the food controller at the present time (January, 1918), *as far as rationed articles go*, works out at 2000 calories only. Therefore, if only moderate work is being done, 1400 more calories must be obtained from unrationed articles, such as potatoes, fish, peas, &c. —a rather large proportion, and possibly liable to lead to mistakes in both directions. On account of the high nutritive value of bread as the basal constituent of diet, it is doubtless best to leave it unrationed, and to use all available transport for wheat alone. The existence of a shortage of food in the world as a whole is, or was at one time, stated to be the fact. This was unfortunate, because many people happened to have heard of the large quantities of wheat in Australia and elsewhere, only waiting for ships to carry it. The manifest untruth of the former statement naturally gave rise to doubts as to whether there was really any basis for other admonitions as to the need for economy. Another point with respect to the deficiency in ships is sometimes forgotten, namely, that it is greatly due to the large number taken by the army for transport and other purposes. The question

of war bread itself is discussed in a subsequent lecture by Professor Hopkins, and I will only mention here that its digestibility and capacity of being utilized in the body is very high indeed, although there have been contrary statements made.

Another point that will be found treated in this volume is connected with that of wheat, namely, the best means of using our own farm land for the growth of food.

I cannot avoid referring to two matters which must give rise to some doubts as to whether there is any real shortage of cereals at all, however unfounded such doubts may be. The first is: Why is the breeding of race-horses and the continuance of race meetings allowed to occur? Admitting the necessity of not allowing the breed to degenerate, it is difficult to see the necessity of more than a very few race-horses. I will make no further remark about race meetings. The second one is more serious. It is the large quantity of beer that is still being made. No manipulation of figures can get over the fact of the loss of food value involved in brewing. Professor Cushny's lecture tells us more about this. There is no real value in alcohol, and careful investigations have shown that the supposed diminution of fatigue is merely apparent and temporary. The fatigue at the end of a day's work is less when beer is avoided. One cannot help the thought that it would turn out to be a national benefit if some totally unavoidable chance made it impossible to make alcoholic beverages. Those who think them a necessity would discover that, so far from this being the case, the capacity for work, mental and physical, is increased. I have no fault to find with those who admit that they take alcohol because they like it, and, in certain circumstances, it may, in moderate amount, be innocuous or

even of some benefit. But the cases in which it does good are abnormal, and the results could be obtained in other ways. It is not, in fact, a necessity.

To return to the question of economy in the use of food, we may note that the point of view changes somewhat at different times, according to what articles are abundant. It seems that, while the supply lasts, it may be the duty of those who can afford to buy the more costly articles to do so, in order to leave the more essential ones for the poorer members of the community. Of course, in normal times this would be looked upon as waste.

I have already mentioned the fact that the household consumption before the war appears to have been unnecessarily great. I say "appears", because the figures are taken on the assumption that the food is actually eaten. Since the "Yapp ration" has been introduced I have made enquiries in several households where casual observation would detect no real deficiency on the table. I am told that, *so long as waste is carefully avoided in the kitchen*, there is no difficulty in supplementing the official ration by unrationed articles up to a proper calorie value. It is evident that much economy is possible in the kitchen, and this is an argument for the extended formation of national kitchens. There is no doubt, however, that the shortage of many articles has entailed more difficulties in the art of cooking. If it has brought the necessity for more knowledge, it will have had some good result. It is not to be forgotten, nevertheless, that the more we are compelled to pay for our food the less we have to lend to the country in the shape of War Loan.

In conclusion, I may refer briefly to two or three points of some importance. Suggestions have been made that when muscular exercise is taken otherwise

than as a part of the daily work it should be curtailed as much as possible, because it involves the consumption of more food. I venture to think that this is a mistaken view. The actual additional food necessary is not great, and the extra appetite may be kept under control. If the exercise taken increases the efficiency of a person doing work of national value in any way, and there seems little doubt of this, the extra food is well spent. The position of those who spend all their time in exercise for amusement's sake is different.

Although the benefits of fresh air seem undeniable, it must be confessed that it is difficult to say why. There is no evidence of real deficiency of oxygen or of injurious excess of carbon dioxide or other products even in rooms that are felt to be "stuffy". It may be an effect of stimulation of the skin by currents of air, as in the experiments of Leonard Hill. Somewhat the same considerations arise in connection with cold baths. More about fresh air will be found in Professor Kenwood's lecture below.

In the discussion of food rations as a whole, the normal healthy individual has been taken as the basis. In the case of those of weak digestion, the possibility of certain articles being incompletely utilized must be taken into consideration.

W. M. B.

WAR BREAD

and its Constituents

Bread as a food-stuff is of supreme economic importance, because it supplies the essentials of human nutrition in a form which is especially cheap and convenient. In the cultivation of corn crops mankind finds its best investment, and the nations that convert their corn into bread attain to an ideal of nutritional simplicity and convenience.

When appraising the relative cost of nutriment as obtained in different foods, we must not, of course, be content to compare the prices per pound of various articles of consumption. We have to reckon the amount of real nutriment obtained for a given sum, which is by no means the same thing. If we apply this test, we discover the real cheapness of bread.

At the present time prices are disturbed and artificially regulated, so that it is more instructive to take our data from a period before the war. The following figures, which give the most practical form of comparison—the relative amounts, namely, of food energy obtained for a given sum—apply to purchases all made in one and the same district during the year 1913:—

Food.	Calories bought for One Shilling.
Bread	10,800
Potatoes	8,700
Quaker oats	7,440
Rice	6,520
Loin of pork	2,010
Rump steak	1,000
Cod-fish	670
Lobster	100

The short list as given will be sufficient to justify the statement that bread is pre-eminently cheap as a food-stuff. It is not surprising, therefore, to find that it always forms a relatively large proportion of the food of the poor. In the case of families with very small incomes, bread often supplies as much as 60 per cent of the whole energy in their food, whereas in middle-class families it supplies less than 40 per cent, and among the wealthy considerably less than this. When prices rise all round under uncontrolled conditions, bread still always remains the cheapest food, and its consumption, unlike that of other foods, tends in such circumstances to increase rather than to diminish.

After the later 'seventies of the last century, and until the beginning of the World War, the British public was accustomed to bread which was absolutely as well as relatively cheap, and although the Sale of Food and Drugs Act, of 1895, permitted the use of many other cereals in bread-making, the British loaf has in practice been nearly always a pure wheaten loaf, of light and porous character, and particularly white in colour. When war broke out we had come to look upon a supply of very cheap and very white bread as part of the course of nature.

When the danger of acute food shortage arose the British public had nevertheless to face the results of a different policy in bread production, and in the minds of some people a certain degree of anxiety arose lest the change should affect the public health. The changes in our loaf which we have had to face are due first to the presence of a higher proportion of the whole grain in wheat flour, and, second, to the presence, or the occasional presence, of cereals other than wheat in the bread. From time to time potatoes also make their appearance. The presence of the more

cortical parts of the wheat grain darkens the colour of the loaf, and the presence of other materials alters its texture, and may also alter its colour.

We as a nation have never been willing to eat what is held to be inferior bread. The black breads (rye breads) which were long the familiar food of the peasants of Europe were always anathema to us. It is most interesting, indeed, to learn from a passage in Langland's *Piers Plowman* that even in the fourteenth century the English poor would "eat no bread that beans came in". They demanded "clean wheat"! No blame attaches to their descendants for displaying similar healthy instincts; but it is right at the present time to bring an open mind to the question as to what constitutes actual inferiority in bread. Is the very white wheaten loaf so superior to every other type of bread that the public welfare must necessarily suffer by its replacement? This question should to-day be approached, and, if possible, answered without prejudice.

In an endeavour to supply an answer it will be worth while to consider, first of all, certain points of general interest connected with the cereals, the group of plants to which wheat belongs.

The cereals are only grasses, but they are grasses distinguished from the majority of their kind by the fact that they store up in their seeds a relatively large amount of nutriment for the growth of the succeeding generation—nutriment in a concentrated form which happens to be highly suited to the needs of man and animals.

At what stage human selection and effort began to play a part in encouraging this desirable quality in members of the grass tribe we do not know. The origin of the cultivated cereals is strangely veiled in obscurity. We know, however, that certain of them

were familiar to prehistoric man; wheat, for instance, was probably used for food long before the remote period when it was carefully cultivated by the ancient Egyptians and the early Chinese.

Throughout the historical period, and probably for longer, agricultural mankind has expended its skill and effort on two main cereal crops. Rice and wheat are, and always have been, the great cultivated crops of the world. Important as are oats, barley, and maize, they have never formed the basal food of really large communities. Climate and racial tastes or capacity have determined whether wheat or rice should form the basal food of a nation. Rice gives a much larger yield per acre, but it makes more demands upon climate than does wheat, and its culture is a more difficult art. The temperature during its six months of growth must reach 70° F. or upwards, and its need for abundant water, supplied always at the right time, calls for special geographical conditions as well as constant attention. Wheat can be grown within a wider range of climatic conditions, and its culture calls for less meticulous attention. A much smaller proportion of a population depending upon it need be concerned in its actual cultivation, and, unlike rice, it can be produced so as to be greatly in excess of local needs. Wheat, therefore, bulks largely in international trade, and industrial communities can always, when transport is available, obtain their supplies from fields far distant. Rice is eaten, so to speak, on the spot. Of the vast world harvest of this cereal only a minute fraction travels overseas. Wheat, as stated, can suffer very considerable varieties of climate, but the character of the climate and of the soil where it is grown affect the characters of the grain, a fact which, as we are to see, has had interesting and important economic consequences.

The nations of the West have adjusted themselves to the eating of wheat. Its special properties have in course of time determined their tastes, and they would doubtless seriously suffer if in their food wheat had to be largely replaced by any other cereal. Yet, after all, something like three-fourths of mankind dispense with wheat, and rice alone is the basal food of millions of Asiatics. What would be really missed by wheat-eating nations, if their special cereal were to fail them, is not any special nutritive quality of the grain, but the leavened bread with its light spongy texture which wheat alone among cereals can yield.

Wheat contains certain protein material known as gluten, which confers special properties on the dough made by mixing wheaten flour with water. When yeast grows in the dough it ferments the small quantities of sugar present, and bubbles of carbon dioxide gas arise in the process. Now, because the gluten makes it tough and coherent, the wheat dough retains these bubbles, and during the baking the bubbles first expand and are then fixed by the drying and hardening of their walls, so that the bread gains its characteristic light and porous structure. Flours made from other cereals which are devoid of gluten, when mixed with water and fermented with yeast, offer no resistance to the escape of gas; so the product when baked is solid and heavy and without porosity. Cereals without gluten cannot yield "loaves" in our sense of the term, and wheat gains pre-eminence in consequence. For the production of such loaves, however, the properties of yeast are as essential as the properties of wheat. It is interesting to note in parenthesis, as an illustration of the way in which national industries may interlock, that if distilleries were closed down—a possible policy, not without appeal to many people—the trade of the baker would

be dislocated for lack of the yeast which, now that none comes from Germany, has to be provided by our own distilleries. If we are to have leavened bread, we must have yeast, and if the latter is to be grown, we must afford the carbohydrate food which it demands. As when it grows the yeast inevitably produces alcohol from the carbohydrate, it would be very wasteful not to distil and recover the spirit. It comes to this, then, that if we want leavened bread we must keep going a considerable proportion of our distilleries. This does not, of course, mean that the alcohol need all be drunk. It has abundant uses in industry.

To return to the main point. Wheat unmixed gives us the best material for a well-piled loaf, but it is desirable, at a time when the actual nutritive value of a food is, after all, of more importance than its æsthetic qualities, to enquire how far, if at all, wheat is superior to other cereals as actual nutriment.

Wheat is doubtless an admirable basal food because it supplies energy and protein in right proportion. Like other cereals it is deficient in fat; when this is added, however, white wheaten bread, if we base our opinion on crude analytical data alone, would seem to supply all the factors necessary for nutrition in excellent proportions. Experiments on animals show, however, that wheat when compared with other grains has no outstanding merits as a nutrient. No cereal, indeed, forms a perfectly balanced food when eaten to the exclusion of everything else, and recently won knowledge concerning the details of nutrition has made clear some reasons for this. Certain proteins found in vegetable foods differ in important respects from the proteins of our own living tissues, and there may be in consequence considerable lack of economy in the conversion of the former into the latter, or in

the general utilization of proteins in the body. This is true of the cereal proteins. Now where there is this lack of correspondence between the nature of a food protein and the needs of the tissues, the economy of utilization may be greatly improved by the addition of even a small quantity of protein derived from other food-stuffs. A very little casein from milk, for instance, greatly improves the value of a dietary when it replaces a proportion of cereal proteins, which may yet be forming the basal supply. Such considerations as these partly explain the advantages of mixed dietaries. Now bread is in practice not eaten alone, and deficiencies, such as those just mentioned, are in reasonable dietaries largely compensated. We however, are considering the qualities of bread in particular. It may be stated with confidence that there is no evidence to show that wheat is really a better nutrient than, say, oats or barley. While therefore the addition of these to the loaf cannot do harm, it may, for reasons such as those just discussed, actually improve the protein supply available.

To the second characteristics of the war loaf—its inclusion of parts of the grain which were wholly removed from the flours yielding the white loaf of peace time—we must afford more discussion. Controversy concerning the relative merits of whole-meal breads and refined-flour breads has long been with us. It has sometimes been associated with fads, and it has often been conducted with bias. It was acutely revived in a somewhat modified form by the journalistic support of a so-called "standard" bread a few years ago. Such controversy it seems might well have continued indefinitely. The special condition of the present is that all are compelled to eat a bread which approximates to the whole-meal type, whether their instincts, predilections, or experience are in

favour of it or otherwise. As this type of bread must continue to be the national supply for some time to come, and, as its use may possibly outlast the war, there is some excuse for considering rather fully such facts as are known to bear upon the relative food value of breads made from various types of flour.

Although natural taste and preference doubtless played their part in so firmly establishing the use of a white porous loaf in this country, circumstances have done a good deal towards the creation of the taste, and historically events have acted and reacted upon each other in an interesting way to determine the nature of our bread-supply in successive periods.

If Britain could have continued to grow wheat enough to feed her population we might still be eating the somewhat dark-coloured nutty-flavoured bread of the stone-mill period; while windmills and watermills would still be familiar to the countryside. But so far back as when the Germans were last on French soil we grew but half the wheat we ate, and when they struck again we were growing but a fifth.

Now, while home-grown wheats well suited the miller who used to grind them between stones, the imported wheats gave him trouble. When the latter came to preponderate in the market a revolution in the milling industry occurred, and the use of steel rollers in place of stones became almost universal. Once roller milling was established it was easy to make very white flour from the foreign wheats, and, these being for the most part "strong" wheats in a sense to be presently discussed, our bread became not only whiter but lighter and more porous than in the days of the stone mill. It is worth while perhaps to go more fully into the details of these changes.

The old-fashioned stone mill had in its way reached great perfection as an instrument. Great care was

given to the preparation of the grinding surfaces of the stones. The lower stone was fixed, while the upper, exactly balanced above it, and separated from it by a minute interval, revolved at high speed. The grain was fed into the space between them through a hole in the centre of the upper stone, while the lower stone was grooved to allow escape of the products of grinding.

All, or nearly all, of the wheats which were grown at home forty years ago had a tough husk and a soft kernel. The stones stripped off the former without breaking it up unduly, while they ground the latter fine. Subsequent sifting sufficed to separate a flour which made a white loaf, while the outer parts of the grain were fed as "offals" to animals. Now, foreign wheats, or the greater number of them, are hard in the kernel and thin and brittle in the husk. By the time the stones of the old-fashioned mills had ground the former fine enough, the husk had also become much disintegrated, and proper separation by sifting became impossible. So, for a good many years, the use of hard foreign wheats led to dark-coloured loaves. Meanwhile, however, the roller process was developing, and American millers found that roller mills could deal satisfactorily with the hard thin-skinned wheats grown in their country. Very white flours could be obtained, and these were exported to England, where they attracted the public taste and competed with great advantage against the darker flours got by stone milling. English millers, in self-defence, adopted and developed the roller process.

Roller-milling plants show a remarkable adaptation of means to ends, and a large and well-run modern flour-mill commands the admiration of all who inspect it. The grain is transported from one department to another, and is generally dealt with from first to

last by mechanical means. It enters the grinding machinery proper as a particularly clean product. It is ground between rotating steel cylinders, which, according to the special work required of them, have their surfaces either smooth or fluted. A pair of these is so mounted that the distance between the two can be nicely varied and adjusted. Both are made to revolve so that the adjacent surfaces, between which the grains are nipped, travel in one and the same direction, though with different velocities. The correspondence in direction diminishes friction, while the difference in velocity of rotation secures that the grain shall be torn apart as well as crushed. It suffers shear as well as pressure, though the relative degrees of shear and pressure vary in different stages of the milling process, and may be varied if necessary at any one stage.

The wheat is first passed between a pair of fluted rollers, of which one revolves appreciably faster than the other, so that the grains are torn asunder without suffering very much actual grinding. This process is technically known as a "break". The products obtained at this first stage are immediately "separated" or "purified". They are sifted, that is, through silk of properly chosen mesh, and the sifting is assisted by the application of a current of air from a fan, which blows particles of husk away from the heavier particles of broken kernel. A certain amount of actual flour, but usually not much, appears at this stage.

The ruptured kernels are now passed between a pair of smooth rollers rotating at nearly identical velocity. At this stage there is more crushing than tearing, and the process is known as "reduction". Again the products are separated, and this time a large proportion of flour is obtained with a small quantity of well-ground offals. Part of the grain,

however, still remains in the form of particles which are more or less coarse. This fraction undergoes a second "break" process, passing between grooved rollers which are nearer together than those used for the first break, and usually have finer grooves. They run, as before, at unequal velocities. A second "reduction" follows, then a third break, and maybe, even a fourth, with the rollers coming each time closer together. Each break is followed by a reduction, and separation always follows both. Flour or husk which comes out fine enough at any one stage is not passed on to the next, so that waste of power is avoided. The small amount of flour obtained at the first break is of inferior quality, and is apt to be a little dirty, because the fold or furrow which runs along the surface of the seed tends to retain dust or dirt, and this is not removable before the wheat has been torn by the first pair of cylinders. The first reduction, on the other hand, yields a large quantity of fine white flour, which comes upon the market as "patents". The immediately succeeding stages also yield high-quality flour, but the latest breaks and reductions give products containing a good deal of husk, and are known as "seconds". When the patents or "extras" are mixed with the seconds we have "straight-grade" flour, which contains about 70 per cent of the whole wheat berry.

What I have been able to say can give, of course, only a very inadequate understanding of the milling process to those who have not seen it; but it is perhaps enough to show that it has reached great perfection. It is interesting to remember that its remarkable development was stimulated, at any rate at first, not so much by the demands of the consumer as by the special properties of certain wheats. The flours which are considered by the trade, and, for

that matter, by the public, as of the finest quality contain relatively but a small proportion of the whole grain. "Patents" flour, for instance, contains only about 36 per cent. The so-called "straight-grade flour", a mixture of the finer qualities with "seconds", represents, as already stated, about 70 per cent of the grain, this being the largest proportion which usually went into a white loaf before the war. The old stone mills on the other hand used to yield a flour containing 80 per cent, and the flours used for our war bread have contained from 80 up to 90 per cent of the whole wheat.

When the miller increases the degree of "extraction"—to use the technical expression—it means, of course, that a greater relative amount of those parts of the grain which lie nearest to the husk go into the flour. The chemical and physical characters of these parts are somewhat different from those of the inner part, the white endosperm of the kernel, which was found alone in the really white loaf. Another constituent of the grain which has characters of its own is the germ or embryo—the representative of the future young plant. It is somewhat difficult to trace the exact fate of this during the process of milling. It is safe to say, however, that, while the modern process practically eliminates it from the flour, the stone mill left in a considerable proportion, while a flour containing 90 per cent of the grain will, however milled, contain nearly the whole of it.

It is clear that the real point at issue in the controversy concerning the relative merits of white and brown bread is the actual nutritive value of these special parts of the wheat berry which are absent from the one bread and present in the other. Before considering this important question further, it will be well to deal briefly with a point which, though of

comparatively small importance in a time of shortage, related as it is to degrees of superficial excellence in bread rather than to its real nutritive value, is one to which in normal times much attention is given.

A complaint which has been often heard is that war bread is far from being a uniform product. It may be satisfactory in one locality but much less so in another, and it may vary from time to time in the same locality. Doubtless much of this variation has been due to a difference of skill among bakers, who, when the necessity for a new policy first arose, were forced to deal with unaccustomed material. It has been partly due, perhaps, to varying admixtures of the wheat with other cereals, but it has been also due to variation in the nature of the wheat itself. In normal times it is possible for the milling and baking trades combined to adopt such a policy as will secure more or less uniformity in the bread-supply. Wheats of different quality can be so combined in the flours on the market as to keep up an average standard. Difficulties of supply and of transport have since the war interfered with such arrangements, and there has been much less uniformity in the local and general supply. Now the effect of variation in the wheat upon the quality of the loaf depends upon some very interesting facts.

Wheats are said to be strong or weak. By a strong wheat is meant one capable of yielding from a given weight of its flour a relatively large well-risen loaf of uniformly porous texture. The same weight of flour from a specially weak wheat will make a small flat loaf. It was earlier stated that the production of a leavened loaf is only made possible at all because of the presence of gluten in wheat flour. Its properties, we have seen, confer upon the dough the power of retaining gas, and so ensure the rising of the loaf during

fermentation and baking. It would seem, therefore, that differences in strength in wheats are likely to depend upon variations in the amount of gluten contained in the grain. This is not the case. Owing to the interesting investigations of my colleague at Cambridge, Professor T. B. Wood, we are now clear as to the real factors at work. The yeast plant directly ferments sugar, and if, during the rising of the dough, it has to depend mainly upon the small amount of sugar present as such in the flour, the amount of gas given off from the fermentation will be small, and the dough will rise to a correspondingly small degree. Strong wheats, however, contain an enzyme capable of rapidly converting into sugar some of the starch of the flour made from them as soon as it is mixed with water, so that the yeast is stimulated, fermentation of the dough proceeds more rapidly, more gas is evolved, and there is a greater expansion of the dough. Weak wheats contain less of this enzyme. In this way differences in the ultimate size of the loaf are accounted for. The shape and texture of the loaf depend upon a different factor. Because it is a substance which when in solution displays colloidal properties, the physical state of the gluten in the dough is profoundly affected by the salts which are also present. Phosphates make gluten tough and elastic, exaggerating, therefore, its power of retaining the gas bubbles from yeast fermentation. Chlorides and sulphates, on the other hand, tend to make it hard and brittle, and so reduce that power. Now strong wheats are found to contain more phosphates and less chlorides and sulphates than weak wheats. It is for this reason that the former yield a porous, well-shapen loaf and the latter a loaf which is flat and heavy.

Home-grown wheats are usually of the weak type, and in order to make flour which would bake such

bread as we were eating before the war the miller had to blend the wheat he ground with a proportion of hard wheat from Canada, America, or Russia. Normally it is possible by such admixture to secure a satisfactory average strength in the flour supplied to the baker. At the present time it is less easy to do so. War bread must remain an article less standardized than the bread of peace time.

We return now to what is at the present time a more important question, namely, the actual nutritive value of our war bread. It is really, as we saw, a question of the nutritive value of those parts of the grain which are excluded from the white loaf.

Controversy concerning this point has proceeded somewhat on the following lines: The supporters of brown bread or standard bread point to the fact that material rich in protein lies immediately under the husk, and this it is wasteful to remove. The germ, again, is specially rich in protein. They insist also upon the fact that breads containing more of the outer parts of the grain are very much richer in phosphoric acid than white flours, and the human body requires phosphates for its nutrition. Further, some of the advocates of whole-meal bread have insisted upon the supposed importance of enzymes contained in the germ. To such arguments the supporters of white bread have replied that, while it is true that the presence of offals in the bread increases somewhat the amount of protein, this advantage is more than lost, because the outer layers of the grain are less digestible than the endosperm. On a balance there is loss rather than gain, because the materials of the coarser loaf are less available to the body. As to the phosphoric acid, while brown bread undoubtedly supplies more, white bread contains enough, so there is little point in the difference. The germ in any case only

amounts to some 1½ per cent of the grain, so that its properties cannot have much quantitative importance. As for the enzymes it contains, there is no proof that they are of use, and in any case they are destroyed in the later stages of baking. The presence of the germ, moreover, interferes with the keeping qualities of the flour.

The issue, as already suggested, has often been obscured by bias. Enthusiastic food reformers often start with preconceptions, and are supported rather by their own enthusiasm than by facts. Suggestion counts for a great deal in matters of diet, and real evidence only comes from carefully organized and controlled observations. On the other hand, the millers, though they have adjusted their methods to the needs of the moment with the utmost loyalty, cannot be expected to believe readily that the capital and labour expended during half a century on perfecting the art of producing the pure white loaf have been misspent. Unless very clear proof is advanced that there is definite advantage to be gained by retaining more offals in the flour, trade interests will be on the side of keeping them out. "Offals", it may be here suggested, though a traditional name for the harder parts of the grain, is an unfortunate one, leading to prejudice.

The facts can only be arrived at by actual experiments carried out upon human individuals under carefully controlled conditions. A considerable number of such experiments have been made, especially in the United States. In this country they have been few, but recently a committee of the Royal Society instituted a careful investigation with the aim of deciding whether there would be a real gain of nutriment to the country if the percentage extraction of our wheat supply were raised from 80 to 90. The

aim of the committee was primarily to decide, not so much whether the absolute digestibility of bread made from one of the flours so extracted is greater than bread made from the other, but whether the gain in the total amount of available human food, which the inclusion of an extra 10 per cent of the wheat must obviously involve, would be more than counterbalanced by inferior digestibility on the part of the product of higher extraction.

In the first period of the experiment twelve individuals took a dietary which included a large proportion of the 80-per-cent bread, and in the second period eleven of these subjects consumed a diet of similar kind but containing a like proportion of the 90-per-cent bread. The results do not represent the absolute digestibility of either bread, but (a more practical issue) the effect of each type of bread upon the digestibility of a mixed diet as a whole.

I quote the results of this investigation rather than those of any other, as the observations were made for a longer time and upon a larger number of individuals than has been usual. The following figures from the Royal Society's report give the percentage of the whole energy contained in the food of the subjects which was rendered actually available for nutrition by the

Diet containing:	Per cent digested and absorbed.											
(a) 80-per-cent bread ...	96.46	96.06	95.77	96.47	95.3	95.1	97.1	97.4	96.2	96.53	95.8	94.5
(b) 90-per-cent bread ...	94.43	94.42	94.02	93.92	93.0	94.7	94.7	94.5	94.2	—	95.9	95.0

Average percentage utilization of energy in food: Bread (a) 96.14; bread (b) 94.50.

processes of digestion. Each pair of figures refers to a separate individual, the same in each case.

It will be seen that the second bread proved, as a matter of fact, to be slightly less digestible than the first, but a simple calculation will show that this decrease in digestibility is not nearly sufficient to outweigh the gain in food yielded by the more complete extraction of the wheat. The authors of the report calculate, after allowing for the smaller digestibility, and also for the fact that the appearance of more of the wheat grain in bread diminishes the amount available for feeding animals, that a substantial gain to the national larder results from the higher standard of milling. The difference between 80 and 90 per cent extraction increases the supply of energy derived from the year's supply of cereal food to an extent which will cover a month's consumption.

The amount of energy made available is the most useful datum for practical guidance when such questions arise, but the Royal Society's experiments deal further with the protein supply, and show that the nation also gains in this as a result of the higher extraction of its wheat.

In a second part of the report experiments are described showing the availability of the energy and protein contained in a bread at 80-per-cent extraction, in which the wheat was mixed with 20 per cent of maize. It was tested upon the same individuals as before, but also upon five additional subjects—making seventeen in all—of whom four were children. The average digestibility of a diet comprising this bread was exactly that of one containing the all-wheaten bread at 80-per-cent extraction.

A third part of the report describes the effect of similar bread containing mixed cereals upon the appetite and health of invalids at sanitoria and of a

large group of munition workers. The observations extended over a long period, and showed uniformly satisfactory results.

It is difficult to see how any test could have been made with greater care and thoroughness, and the results seem definitely to justify the policy of a higher extraction at the mill whenever there is a shortage in the national supply of cereals. If this results in giving us a loaf of darker colour and closer texture, it is a small matter compared with the increase in available human food.

Whether the policy should be adhered to in normal times is perhaps a different question. The public may think it worth while to sacrifice something for the sake of its white loaf. Facts have come to light of late, however, which will always have to be at least carefully weighed in the future. We know now that complete nutrition calls for more than a supply of energy and protein. There are subtler factors. Natural foods which have undergone no artificial fractionation, such as that which wheat suffers from the art of the miller, contain a sufficiency of what—till we know more about them—we agree to call accessory food-factors or vitamines. They are present in minute amount, but they are essential to the health of the body.

Vitamines are discussed in another section, and little need be said of them here. It is well, however, to point out that their importance must not be viewed merely from the narrower standpoint of actual disease and its prevention. Short of displaying obvious disease, the body may at any time be suffering abnormalities of function due to insufficiency in its vitamine supply. Growth in the young may, for instance, be delayed and unsatisfactory. Now at least one of these important substances, commonly spoken of as

the anti-neuritic substance, because in its absence nervous symptoms display themselves, is present in the outer layers of the wheat berry and also in the embryo, but not in the white endosperm. This distribution has been thoroughly established by the careful work of Dr. Harriette Chick and her co-workers.

Bread, it is true, is not eaten alone. A sufficient supply of vitamines may be forthcoming from the other constituents of a mixed dietary. In determining the milling policy of the future this particular deficiency of the pure white loaf must not, however, be left out of account.

ACCESSORY FOOD-FACTORS
(Vitamines)
In War-Time Diets

Introductory.—With the normal conditions of peace the risk of disease from deficiency of the diet in vitamines (accessory food-factors) was one that was never run by the ordinary individual in this country; but a state of war has brought a new threat to the civilian and a dire reality to the soldier in some theatres of war. Public interest in vitamines has been aroused, the glamour of the subject has caught the popular imagination, and more information is constantly being asked for.

In response to war-time needs appropriate researches have been carried out under Dr. Harriette Chick at the Lister Institute, and it is largely the results of those researches which are embodied in this lecture. The exigencies of the circumstances necessitated that the work should be confined to strictly practical problems, and though little has emerged that is of striking scientific interest, yet the importance of the results is great both to food experts and to the man in the street.

The vitamines, or accessory food-factors, are substances which are present in certain food-stuffs in very small quantities. They have never been isolated, and their chemical nature is unknown; they are essential

to growth and the maintenance of health, but small quantities suffice for these purposes.

The term "vitamine" has been adopted in popular usage, and its convenience is certainly great. It was originally invented by Funk, when he thought he had isolated a substance of definite chemical composition; when this was found not to be the case, the word "vitamine" fell into disrepute, as seeming to imply more knowledge than we possess. Many scientists consequently prefer the more non-committal term "accessory food-factor".

Before plunging into this subject in its war-time aspect, it is necessary to give as short a summary as possible of the existing knowledge concerning vitamines, for it is impossible to grasp the difficulties which arise in war-time in connection with them unless something of their properties and distribution among food-stuffs is first understood.

The work on accessory food-factors falls rather into two schools, of which one has dealt with them in connection with the deficiency diseases (beriberi, scurvy, rickets, and pellagra), and the other has dealt with them as factors in growth. Whether, however, there really are any accessory factors which are necessary for growth and not also necessary for prolonged maintenance is a point which is not fully cleared up.

In connection with the deficiency diseases two factors are clearly recognized, the one in the absence of which beriberi develops, called the anti-neuritic or anti-beriberi vitamine, and the one in the absence of which scurvy develops, the anti-scorbutic vitamine. There is a very strong probability that there are also other accessory food-factors, deficiency of which causes rickets and pellagra. It will be necessary to allude briefly to rickets again, but there is at present no real proof that pellagra is a deficiency disease at all, and,

as far as can be ascertained, there has been no outbreak of it specially brought on by war conditions.

The school which has studied the growth factors is mainly located in America, but the foundation-stone was laid by Hopkins in this country about 1906. Two growth factors are recognized, to which the name vitamine has not been given, but they are designated by their discoverers the "fat-soluble A factor" and "the water-soluble B factor". Rather unfortunately, the different points of attack have made it appear as if the class containing the growth factors and the class containing the anti-beriberi and the anti-scurvy factors were separate and distinct, whereas there is pretty good prima facie evidence that "water-soluble B" is the same substance as the anti-beriberi vitamine. The "fat-soluble A factor" is not the same as the anti-scorbutic vitamine, but facts are not wholly inconsistent with the hypothesis that it may be identical with the substance which prevents rickets, and which is occasionally spoken of as the anti-rachitic vitamine.

Since none of these accessory food-factors has ever been isolated as a definite chemical compound, they can only be studied indirectly by their biological action in feeding-experiments with animals. Every method of attack has thus only the one very slow method of test.

The accessory food-factors are characterized from one another by their different distribution among food-stuffs, by their varying stability to heat, by their behaviour to certain other physical and a few chemical tests, and, lastly, by the pathological effects produced in man and animals when they are omitted from the diet. In the case of each factor the experimental animal has been different, so that at present the work does not fall very well into line, but clinch-

ing experiments with monkeys and very careful clinical observations on human beings should make all clear when the preliminary work on lower animals has been done. Sufficient work in certain directions has been carried out to justify many practical conclusions.

With the beriberi vitamine the experimental animal chiefly used has been the pigeon, an animal sufficiently far removed from the human subject to make the identification of symptoms somewhat difficult; but most close observers are convinced that the polyneuritis of pigeons, first produced by Eykman, both from the similarity of its symptoms and the identity of its method of production, is the same as the beriberi of man.

The experimental work on the scurvy vitamine was begun by Holst and his colleagues in Norway, working with guinea-pigs; the identity of the disease produced with human scurvy has likewise been questioned, but is likewise accepted by the closest observers. Scurvy, indistinguishable from human scurvy, has been produced in monkeys by the same methods which produce scurvy in guinea-pigs.

The work on the growth factors has been carried out chiefly by McCollum and his co-workers and by Osborne and Mendel in America, following Hopkins in Cambridge, and the experimental animal used has been the rat. Of these growth factors, as has already been said, the water-soluble B seems to correspond with the anti-beriberi vitamine, while it is not unlikely that the fat-soluble A may prove to agree in distribution with the hypothetical substance which prevents rickets. It is further interesting to note that rickets is a disease of growth. The experimental work on rickets is only in its infancy, and has been conducted with yet another experimental animal—the

dog; it is, however, well known that rickets is produced in monkeys, and the death rate from this cause at, e.g., Zoological Gardens, is reported as high.

As far as war problems are concerned, we are chiefly occupied with the anti-beriberi and anti-scurvy vitamines, for the results of experimental work on growth factors have been insufficiently applied to human needs. Though there is every probability that the number of cases of rickets is increased by war conditions,[1] still this state of affairs is only an intensification of a condition which is sufficiently acute in peace time, and which only education and money can alleviate.

The Accessory Food Factor which Prevents Rickets.—It is now fairly clear that rickets is not the result of a deficiency of the diet in fat alone, as was long thought, but of some accessory factor, generally found in close association with animal fat. Dr. Mellanby and Miss Higginton, working for the Medical Research Committee, have found that a sufficiency of cow's milk, butter, or cod-liver oil will keep dogs free from rickets, but that linseed oil is powerless to do so. Fat as fat is therefore useless, it is some substance associated with the fat which has the value.

At a time of fat shortage like the present, therefore, it can well be seen that butter, milk, and cream should be specially kept for children, while the vegetable fats of less certain virtue should be given to adults; the time is not ripe for a more definite pronouncement than this.

The Accessory Food-factor which prevents Beriberi.—Beriberi is generally spoken of as a tropical disease; it is popularly very generally confounded

[1] See *Infant Welfare in Germany during the War*, pp. 7-8. Report prepared in the Intelligence Department of Local Government Board. H. M. Stationery Office, 1918.

with sleeping sickness, with which it has no possible connection, and there is usually a vague idea in the public mind that it is associated with the eating of polished rice.

Its symptoms are those of a peripheral neuritis; there is loss of power in the arms and legs, and frequently at some stage there is dropsy. The disease is usually accompanied by great wasting, and may suddenly terminate fatally from heart failure. On the post-mortem examination nerve degeneration is found.

The symptoms of experimental polyneuritis of pigeons are also those of a peripheral neuritis. The birds become lame and unable to fly; there is loss of balance, and the head is held in a peculiar retracted position very characteristic of the disease. There is seldom or never dropsy, but death may occur suddenly from heart failure, and the post-mortem examination reveals great nerve degeneration.

Beriberi is most common amongst rice-eating peoples, and among them is almost universally confined to those who eat the rice from which the skin or cortex, together with the embryo, germ, or plantlet have been removed. It is not, however, confined to rice-eating peoples; any diet consisting too largely of highly-milled cereals, whether wheat, maize, rice, or any other grain, will equally well produce it.

Experimental polyneuritis of pigeons is produced in the same way, by feeding decorticated grain; the ordinary white rice of commerce is ordinarily used, but the disease will as certainly result from a diet consisting exclusively, or for the greater part, of pure white wheat flour. Dr. Chick and I have so produced polyneuritis in pigeons, and cases are on record where beriberi has occurred on such a diet among human beings. An interesting story is extant of an old Norwegian ship's captain, which illustrates the point well.

The sailors in Norwegian merchant ships were formerly fed on bread made of whole-meal rye, but a humanitarian movement was set on foot to provide them with better bread, i.e. white wheaten loaves. Soon after this innovation, ship beriberi became common among the crews of Norwegian merchant ships. On board a certain ship the crew were provided with the new white bread, but the captain refused to have anything to do with such new-fangled notions for himself, and always took to sea a supply of the old rye flour. He never suffered with beriberi, and was, furthermore, able to recover his crew when they became affected, by giving them a loan from his store. When, however, his supply began to get low, and he foresaw that there would not be enough for himself, he stopped his dole, and in due course beriberi broke out again among the crew.

It was formerly believed that it was the skin or bran of the wheat or rice grains the presence of which prevented beriberi, but Miss Chick and I have been able to show that, though the bran has virtue, the embryo, or tiny plant, called by millers the "germ", is far more potent. In all modern processes of wheat milling this germ is taken off with the bran; it does not enter into the pure white flour at all, but passes away in the offals. It is very rich in ferments, which interfere with the keeping properties of the flour, and it is consequently banned by the millers. In the Hovis and some other processes of milling the germ is cooked, which makes it able to be kept, and it is then returned to the flour. But, apart from special ways of treatment, the modern roller method of milling deprives the flour of all its anti-beriberi vitamine, and we should be in a very bad position indeed dietetically were we not able to rely on other food-stuffs for our supply of this vitamine.

VALUE OF CERTAIN FOOD-STUFFS AGAINST BERIBERI AND SCURVY

	Against Beriberi	Against Scurvy
Cereals—		
Whole wheat	+ +	o
Wheat germ	+ + +	o
Wheat bran	+ +	o
White wheat flour ...	o	o
Pulses—		
Whole peas or lentils ...	+ +	o
Germinated peas or lentils	+ + .	+ +
Vegetables—		
Fresh cabbage	+	+ + +
Fresh potatoes, carrots, &c.	+	+ +
Dried (any)	+	o
Fruit Juices—		
Fresh orange or lemon ...	Not investigated.	+ + +
Commercial lime	do.	o
Meat—		
Fresh	+	+
Tinned	o	o
Eggs—		
Fresh	+ +	? trace
Dried	+ +	Not investigated.
Cow's Milk—		
Fresh	+	+
Dried	+	o
Yeast—		
Pressed	+ + +	o
Extract (marmite)	+ + +	o

The most concentrated receptacles of it in an ordinary diet, besides the cereals just referred to, are the seeds of other plants and the eggs of animals. A special store of it seems to be laid up to provide for the wants

[1] Table slightly modified from Chick and Hume, *Trans. Soc. Trop. Med. and Hyg.*, Vol. X, 1917, p. 156.

of the young developing organism. In our diet, therefore, there is abundant anti-beriberi vitamine in the seeds of any whole cereals (e.g. Quaker Oats, whole meal) that we may consume, and in any pulses (peas, beans, lentils, &c.). The pulses are subjected to no destructive process of milling, and, unlike the cereals, the vitamine seems to be uniformly distributed throughout the seed; it is certainly not confined to any skin or outer layer as it is in the cereals.

The eggs of fowls are richly supplied with it, and dried preparations, such as Eggo and Cook's Farm Eggs, which really consist of desiccated egg only, are equally valuable.

Another very concentrated source of anti-beriberi vitamine is the yeast plant, which is on the market in the form of a vegetable substitute for meat extracts. "Marmite" is such a yeast extract, and we have found it act with the greatest rapidity, and in very small amounts, in curing the polyneuritis of pigeons.

Most of the other ordinary food-stuffs, meat and vegetables, root, stem, and leaf of the latter, contain a moderate amount of the vitamine; the pulpy part of the fruit, as opposed to the seeds, probably does not. Meat and vegetables are not repositories in which the vitamine is concentrated, but throughout the substance it is thinly diffused.

Cow's milk contains the vitamine in small but apparently fully sufficient quantities. Infantile beri-beri is quite unknown in this country, or in fact in any country save those where babies are breast-fed by beriberic mothers, from which the deduction seems clear that neither by preserving nor by pasteurizing, nor by drying is milk rendered deficient in anti-beri-beri vitamine.

The normal diet of a Western European, containing as it does most of the items just enumerated, is a very

safe one as far as beriberi is concerned. There need be no fear, for instance, about eating white rice, since the diet is so well protected in other quarters.

In all these food-stuffs the anti-beriberi vitamine appears to be well preserved. Dried eggs, dried vegetables, dried milk, and yeast extract seem to be as rich in the anti-beriberi vitamine as the fresh food-stuffs, and it has not been possible to detect that there is any appreciable loss in potency when these foods are kept at room temperature.

Nor is there much loss in value at the ordinary temperatures of cooking, i.e. about 100° C. For instance the value from this point of view of a food-stuff is somewhat, but not seriously, diminished by boiling for an hour. The anti-beriberi vitamine may in fact be said to be comparatively thermo-stable. But with higher temperatures it is a much more serious matter. Cooking under pressure at 110-120° C. destroys the vitamine more rapidly, and if this heating is carried on for as much as an hour the degree of impoverishment of the food-stuff in anti-beriberi vitamine may be extremely dangerous. This important fact has its chief application when the diet consists, to any appreciable extent, of tinned foods, which are heated at a high temperature under pressure for considerable periods in order to sterilize them.

Thus a diet consisting of tinned foods and white bread or rice, consumed over some months, would undoubtedly lead to the ultimate development of beri-beri.

There are therefore two ways in which a diet is likely to be rendered deficient in anti-beriberi vitamine:

(*a*) By consisting too largely of over-milled cereals.
(*b*) By consisting too largely of tinned, or, in any other way, overheated food-stuffs.

But, since the vitamine keeps well, and survives undamaged in whole cereals and pulses, in dried eggs and vegetables, and in yeast extract, the problem of keeping an army supplied with it should never be an insuperable one. It is a problem which will yield to intelligence and foresight, since such dry food-stuffs are easily transported, as long as it is possible to transport any food-stuffs at all, and they can be stored indefinitely until they are wanted.

The Accessory Food-factor which prevents Scurvy.—The properties of the anti-scorbutic vitamine make the problems which arise in connection with it much more difficult to solve. It is a far more delicate and elusive substance, and the difficulty of supplying it when fresh provisions run out is very great.

Scurvy has been known as, *par excellence*, a disease of sailors and arctic explorers; it has ravaged armies and haunted the gold-diggers of the Yukon. In the old days, before potatoes and root-crops were known, it was the scourge of households at the end of the winter, when the supply of fresh meat had run out. The need of those days may have given rise to the idea of our own time that a dose of medicine is needed in the spring "to clear the blood". Scurvy is, in fact, a disease of want of fresh food, and where that lack persists over some months scurvy will assuredly develop.

The symptoms consist, at first, of fatigue and disinclination to move, then hæmorrhages appear in any part of the body or internal organs. There is sponginess of the gums and loosening of the teeth, which ultimately fall out, and there may be, especially in children, brittleness of the bones.

A similar condition may be produced (Holst) in guinea-pigs by depriving them of fresh vegetable food, and it is slowly cured when the fresh food is restored. The assumption seems perfectly justified

that guinea-pig scurvy is a condition similar to human scurvy, and is produced and controlled by the same conditions. Acting upon this assumption, all our experimental work on scurvy in connection with war problems has been done on this animal.

The anti-scorbutic vitamine—as far as we have been able to ascertain by experiments on the minimum doses of different food-stuffs, needed to protect guinea-pigs from scurvy—is abundantly present in fresh citrus fruits, e.g. oranges and lemons. Fresh lime-juice, however, is disappointing, and commercial clarified lime-juice is quite useless. Fresh leaves, such as cabbage leaves, are as rich as oranges and lemons, but roots and stem-tubers, carrots, potatoes, and onions, for instance, contain it less abundantly, though it is appreciably present. Fresh meat and milk contain even less.

It is not present in ungerminated seeds, but, as was discovered by Fürst, develops in them immediately on germination, so that peas or lentils, after twenty-four hours' germination have, weight for weight, a value approaching that of fresh cabbage.

But if fresh fruit juices are squeezed out and kept, or if cabbage leaves or milk are dried and kept, the anti-scorbutic vitamine will gradually suffer loss, and in a few weeks or months, though they may be excellent articles of food in all other respects, the vitamine is reduced, and with an exclusive diet of food-stuffs so treated there is undoubted danger of scurvy.

In addition, the anti-scorbutic vitamine is much less thermo-stable than the anti-beriberi vitamine. At room temperature, as just described, it disappears spontaneously in a few weeks, or sometimes even days, according to the particular food-stuff. In cold storage it is better preserved, and it may last some months.

At the higher temperatures, such as that of cooking

and sterilizing, its disappearance is much more rapid. Boiling for an hour gravely diminishes the amount, and after sterilization at 120° C. for an hour the vitamine is reduced to a very small proportion of its original amount. Even the pasteurization of milk, at temperatures below boiling, seriously diminishes the vitamine content, and it is necessary to remember that prolonged cooking at a low temperature will involve as much risk as rapid cooking at a much higher one. Thus the use of such an apparatus as the hay-box may have a very serious drawback when food-stuffs are submitted to moderate temperatures for very many hours. This question is being further investigated by Dr. Delf, as being one of considerable economic importance. Among poor families the chief source of anti-scorbutic vitamine is their meat and vegetables, especially potatoes. If these are left to stew for hours in the hay-box, the diet may become definitely deficient in anti-scorbutic vitamine; more particularly is this likely to be a danger when the price of fresh fruit is as high as it is now.

Since the vitamine will not keep, even at room temperature, it is clear how difficult is the problem of keeping armies, far from their bases, constantly supplied with fresh food.

Beriberi in War-time.—That there was a need for research in this direction in connection with the war was first indicated when Colonel Martin, Director of the Lister Institute, wrote home from Lemnos to his assistant, Dr. Chick, saying that a few cases of beriberi had developed on Gallipoli. On receiving this information the problem was to devise any easily portable addition to the ration, which should be rich in anti-beriberi vitamine.

What the ration was which produced these cases we have never been fully informed; it probably con-

sisted mainly of bread made from white wheat flour and of tinned meat.

It is interesting to notice that the official specification requires that army-bread flour shall consist of pure white wheat flour. It is supplied by the contractor and baked by the army cook, and there is little opportunity for adulteration with offals. The loaf is, therefore, what it purports to be, a pure white wheat loaf. It is otherwise with army biscuit; in this case the specification is not so clear, and, as the biscuit is supplied as a finished article, an admixture of offals is much more difficult to detect, and in practice a large percentage of offals, i.e. germ and bran, frequently enters into the composition of the army biscuit. So much, indeed, is included that the biscuit alone is a perfectly safe diet against beriberi. We have fed pigeons exclusively on several types of army biscuit, and have kept them in perfect health for three months, polyneuritis in pigeons usually developing in from fifteen to thirty days on a vitamine-free diet.

Army biscuit, therefore, owing to its addition of germ and bran, is an adequate food against beriberi, but army bread is not, as experience in the field has also shown.

We have therefore recommended that in the Eastern campaign, at any rate, all bread or biscuit used in the rationing of armies should be required to contain a proportion of the offals.

We have further recommended that the ration should include a soup square made of pea flour and Marmite (yeast extract). Such a soup square has been in use for some time, but as at the same time the diet has been enriched in other ways, it is not possible to argue that the disappearance of beriberi is due to its introduction.

For hospital use we have recommended, in addition, some preparation of dried egg.

It may appear to many that the occurrence of a few cases of beriberi in Gallipoli was a matter of negligible importance, and that the modification of the diet of an army to meet such a slight roll of sickness is quite unnecessary; but it must be remembered that for every case of deficiency disease that is actually acute enough to become a casualty, there may be innumerable others with nutritional disturbances, whose efficiency is impaired, but who are not bad enough to go sick. It takes at least three months of deficient diet to fall sick of beriberi, but the organism is running down all that time, and though many might not be exposed to the deficient diet for long enough to fall sick of it, yet their health would be impaired and their reserves undermined.

The lessons learnt in Gallipoli did not come in time to save the white soldiers in the advance to Kut and during the siege. In this case the ration was white army bread and meat, partly fresh, partly tinned, with very little variation. The men began to go sick, with pains in their shins and general malaise, which in many cases became acute beriberi.

Among the Indian soldiers in the siege the course of events was altogether different. The ration for Indian soldiers is totally different from the British one. Two of the principal items which it contains are *atta* and *dhal*. *Atta* is very coarsely ground wheat flour, and *dhal* is any kind of pulse—pea, bean, or lentil. Thus the Indian dietary contains two items very rich in anti-beriberi vitamine. The Indians, in fact, never had any case of beriberi, and, what is more interesting, when, during the siege of Kut, the white wheat flour ration for the British troops ran out, *atta* was served out to them instead, and from that time

beriberi disappeared from among them, as is described by Colonel Hehir in the Mesopotamia report. A better instance than the foregoing could scarcely be wished for to show that beriberi develops on a diet consisting too largely of overmilled cereals, and clears up when the whole grain is served out.

Scurvy in War-time.—Though the Indian soldier's diet is so satisfactory from the beriberi standpoint, it is not so from that of scurvy. When on his ordinary diet, the staple of which is *atta*, *dhal*, rice and fresh vegetables, he is not far from the scurvy margin, and when, as was the case in Mesopotamia, fresh fruit and vegetables disappear from the dietary, he is in a very bad way indeed, because he has not the fresh meat of the British soldier. Very many Indians will not eat meat, and those who do generally boil it to rags, so that much of the anti-scorbutic vitamine is destroyed by the prolonged heating. Scurvy among Indian soldiers in Kut was severe, except among the Gurkhas who ate meat; it improved considerably when at last, in the later stages of the siege, many of the men were prevailed on to eat horse and mule meat.

It may give cause to wonder that lime-juice, which has ranked even in the public mind as a panacea against scurvy, has scarcely yet been mentioned in this connection. Those who saw it in use in Mesopotamia got the impression that it was powerless, and our own experiments seem to show that fresh lime-juice is much weaker than fresh orange- or lemon-juice, and that the very much older commercial lime-juice is useless. The reputation that it has enjoyed it seems to have acquired undeservedly from lemon-juice. In the old naval records very great value against scurvy is ascribed to lime- or lemon-juice. These records date back to the end of the

eighteenth century, but information obtained from Messrs. Rose goes to show that neither lime-juice nor lime fruit was imported into this country till 1859. Prior to that date lime fruit and juice were certainly picked up by ships cruising in the West Indies, but in the majority of cases it would seem that the term "lime" was used indifferently for limes and lemons, and it may be the lemon which won the reputation in scurvy. The history of the use of lime-juice and lemon-juice in the navy is under investigation at the present time by Mrs. Henderson Smith.

A reliance on lime-juice in such a campaign as the Kut campaign would land an army in a very bad position, and it is apparent that the problem of such a campaign is a very difficult one. For, to sum it up briefly:

1. The anti-scorbutic vitamine does not survive long except in living tissues.
2. The only living tissues which can be easily got up long lines of communication to advanced posts are animals which can be made to walk there.
3. But many native Indians will not eat animals.

There is, however, a possible solution in the discovery made by Dr. Fürst, a colleague of Professor Holst's, that the anti-scorbutic vitamine develops in seeds immediately on germination. We have germinated the *dhal* of the Indian soldier's ration, and find that its value after twenty-four hours' soaking and twenty-four hours' germination is as good as that of many fresh vegetables. Here, therefore, we have ready to hand a means of meeting the difficulty. The germination on a large scale needs a little care, for if the seeds are too moist or in too thick layers they will ferment instead of germinating.

During the necessary cooking which follows the germination a good deal of the anti-scorbutic value is lost. The loss is minimized if the cooking is made as short as possible and if the *dhal* is steamed, not boiled. If it cannot be steamed it should be boiled in the least possible amount of water, and the water consumed as soup or stew. If these precautions are observed, it is believed that scurvy can be prevented among any Indian troops receiving the *dhal* ration.

The Eastern theatres of war are not the only field of the deficiency diseases. We do not know how near our prisoners of war in Germany may have been to scurvy, but a word of warning should be uttered to anyone who thinks of helping them in that respect by sending them dried vegetables. Articles have appeared in the papers urging that by drying cabbages it is possible to send in a match-box all the virtue of the fresh leaf. It is not possible to do so.

Scurvy broke out in the American Civil War and in the Austrian army in Hungary in 1720, and in both cases dried vegetables were tried and failed completely. Kramer, a surgeon to the Austrian army in the above campaign, after trying unsuccessfully many kinds of dried herbs, wrote: "Scurvy is the most loathsome disease in nature, for which no cure is to be found in your medicine chests—no, not in the best-furnished apothecary's shop. Pharmacy gives no relief, surgery as little. But if you can get green vegetables, if you can prepare a sufficient quantity of fresh, precious, anti-scorbutic juices, if you have oranges, lemons, or citrons, you will without other assistance cure this dreadful evil." So that even then he knew the importance of freshness, but nowadays we seem almost to have forgotten it.

At the end of the spring of 1917 there were even cases of scurvy in some of the northern towns of Eng-

land. Many of our poorer people, and those in work-houses and institutions, depend very largely on potatoes for their anti-scorbutic supply. Last spring the scarcity and high price of potatoes put them out of the reach of many, and though there were less than a hundred cases of overt scurvy, there must have been many more hovering on the brink, who, with a few more weeks of the same diet, would have developed it too. They were saved by the new potato crop and the rush of green vegetables which had been held back by the exceptionally long winter.

Infantile Scurvy.—Lastly, there is the problem of infant feeding, which is always a problem, but is intensified by war conditions.

Barlow's disease, or infantile scurvy, is a disease of which not many acute cases are seen, but there seems a reasonable likelihood that many ailments which are put down to teething or are left undiagnosed are nothing more nor less than incipient infantile scurvy. Fretfulness, tenderness on handling, a failure to put on weight, "baby not doing well", these are all too familiar in infant practice, and there is reason to hope that a proportion of such cases might clear up instantly on a course of anti-scorbutic.

Fresh cow's milk is not rich in anti-scorbutic vitamine; there is just enough if the diet consists wholly of milk, as is the natural arrangement, but if the milk is pasteurized or sterilized, or dried, or diluted with starch, the proportion of anti-scorbutic vitamine in the diet is reduced and risk is being run. To use cow's milk, entirely untampered with, is the ideal arrangement, but the milk is seldom clean enough, and sometimes the baby cannot digest it. If, then, it is necessary to interfere with the milk in any way, additional anti-scorbutic must be added.

Orange-juice is undoubtedly the best of such anti-

scorbutics, meat-juice and grape-juice are much less potent, but any of the three is too dear under war conditions for many poor mothers. Correspondingly with war conditions the use of dried milk for infants has increased, and the need for a cheap anti-scorbutic safeguard has therefore increased also. We have tried to devise one, and are of opinion that swede-juice is to be recommended. Recent unpublished researches show that it is greatly more active than carrot- and beetroot-juice, and the swede is a cheap vegetable. The juice must be prepared fresh daily, but the preparation is very simple. The raw swede is grated on a kitchen grater, and the gratings are squeezed by hand through muslin, when the juice runs out freely. One or two tablespoonfuls would probably be ample to protect an infant.

It is most important that the wisdom of giving added anti-scorbutic when the milk is other than fresh cow's milk should be fully appreciated. Some authorities are of opinion that it is unnecessary, and undoubtedly many children will get through somehow without it, but they will not have received the optimum conditions of nutrition which we should seek to give to every child.

It is to be hoped that the Ministry of Health, when it comes to be established, will take up these fundamental questions of infant feeding; an adequate provision of fresh cow's milk must be made for every child, and the deficiency diseases of rickets and scurvy must cease to exist.

E. M. H.

Alcoholic and Other
BEVERAGES IN WAR-TIME

The purpose of this paper is not to discuss the general question of the value or the noxiousness of alcohol. Most educated people now have definite views on the subject, and I do not propose to bring forward arguments in favour of either of them.[1] My objective is a comparatively narrow salient of this great question—namely, how far alcohol may be regarded as a food, and that in special reference to the present conditions of the country. In that connection some references will be made to other beverages which are generally regarded as enjoying a less equivocal position, and are associated with the domestic hearth rather than the public-house.

Alcohol in its various forms of beers, wines, and spirits is of course the same substance, but in each of these it is accompanied by other bodies of different qualities. It is impossible to take up these, however, partly because they are largely unknown. The essential feature in all is the alcohol, be it drug, food, or poison, or all three. The other constituents act mainly if not entirely as flavours. Alcohol when swallowed is taken up rapidly by the walls of the stomach and

[1] To those who wish to pursue the alcohol question in other directions I may commend a small book published by the Board of Control (Liquor Traffic), which gives all the known facts and none of the fictions in regard to drink: *Alcohol, its Action on the Human Organism.* H.M. Stationery Office, London, S.W.

bowel, and passes into the blood, to be carried all over the body. It does not have to undergo digestion, like most foods, and this has been supposed to give it special value as a rapid method of giving food. As a matter of fact, it does not seem to be assimilated any more rapidly than the simple sugars.

When alcohol reaches the blood and tissues, these very soon begin to oxidize it or burn it, and it disappears practically completely. No more escapes from the body unchanged than of a corresponding amount of sugar, and the decomposition products are the same whether alcohol or sugar is burned. Now we know that alcohol in the form of a spirit-lamp can be used as a source of heat outside the body, and the same is true in the tissues; alcohol, therefore, serves as a sort of internal spirit-lamp to keep up the body temperature. But a spirit-lamp is also capable of doing work, as is shown in many toys in which an engine is driven by a sponge soaked in alcohol; and it must have been a grief to some to see alcohol used even to drive motor-cars in late years. The combustion of alcohol outside the body can therefore be utilized for work as well as for heat. Can the body utilize alcohol to do work in the same way? The answer is beyond question. The most careful examination by measurement of the amount of work done has shown that the human muscles can utilize alcohol as a source of power just as they can utilize sugar and just as the engine can draw its power from burning alcohol. And the change is the same in each case: the alcohol is burned in the body just as in the engine, and with the same completeness. The only difference is that the alcohol is destroyed in the body at a much lower temperature, owing to the activity of certain special conditions and powers which we call enzymes. Alcohol is thus a source of energy to the

tissues; but here it must be explained that energy is used in the technical sense and not in the popular one. A man may be supplied with energy by alcohol, but he is not on that account an energetic man.

Alcohol thus serves as a source of heat and work in the human tissues just as sugar and starch and bread and most of our foods. And, if you wish, you may describe it as a food, or as having food value like these other substances. I do not know that this is a safe thing to do, however, for then the question arises whether it is a good food or not. Now the criteria of a good food are not very easily satisfied, because the best foods are those which only serve as a source of heat and work, and have no other action either on the digestion or elsewhere. For example, ripe apples and bread act only as sources of energy, and are palatable, and are thus first-class foods; green apples are almost as valuable as sources of energy as ripe ones, and appear to suit youthful tastes, but upset the digestion, and are therefore not first-class foods, but only second- or third-class, and may even be regarded as poisons. Alcohol is a valuable source of energy, and also appeals to many tastes, but it upsets the brain. It cannot be regarded as in the first class of foods, but I leave it at that—somewhere between bread and green apples as a food. It is not only a food in the strict sense, but also a drug or poison, and if alcohol is to be classed as a food you must also accept such things as green apples, glycerine, vinegar, and even morphine in the same category, for these also undergo oxidation in the body, and become a source of heat and work in the same way.

The ordinary foods on which we draw for power are bread-stuffs (carbohydrates), fats, and meat-stuffs

(or proteins). Can we utilize alcohol to replace these in the supply of fuel? This is the crucial question in the estimate of the food value of alcohol, and it has long been a subject of investigation and a battle-ground for the supporters and denouncers of the use of alcohol. There is no longer room for doubt, however, that alcohol can replace a certain amount of bread-stuffs as a source of heat and work in the human body; about one-fifth of the total energy required can be supplied by alcohol. And if alcohol is taken, not as a substitute for part of the bread-stuffs, but in addition to the ordinary dietary, it is utilized for heat and work while the bread-stuffs are stored up in the tissues for future use: the body becomes a hoarder. And here we find the chief difference between the behaviour of alcohol and sugar in the rôle of food-stuffs. Sugar, which is chemically a not very distant relative of alcohol itself, and which, on the other hand, may be taken as the type of the starches and bread-stuffs in general, can be stored as a reserve in the body, while alcohol cannot be laid up in this way, but must be consumed. An analogy may be drawn with the household economy, in which flour and cereals in general can be stored better than potatoes, and we are therefore urged to use the latter and spare the stock of cereals for a time when there may be a scarcity. In the same way the body cannot store alcohol, and uses it for heat and work, and stores its sugar for future use. The final result is much the same in either case: when sugar is taken it is utilized as a source of work, and part of it may be stored; while when alcohol is taken it is utilized for work and the sugar is stored, or the reserve of sugar already present is not drawn upon. Alcohol may likewise be utilized instead of fats in the body, and, if it is taken in addition to the ordinary diet, fat

is deposited as a store. The tendency to hoard fat when alcohol is taken in quantity is, of course, a familiar enough observation.

As regards the proteins or meat-stuffs, alcohol cannot supplant these, because the proteins contain nitrogen, while alcohol is free from it. Now nitrogen is a necessary constituent of the food. The nitrogenous compounds serve to replace the waste of the human machine, and they also are available as a source of energy for heat and work. In their first function of replacing the waste the proteins cannot be substituted by either alcohol or sugar, but as a fuel for the body either alcohol or sugar may serve instead of the proteins in equal measure. It is true that in some experiments it has appeared that alcohol was not equivalent to sugar in reducing protein waste; but this has been satisfactorily explained by the fact that a sudden change to alcohol or other substitute for bread-stuffs disturbs the digestion at first, and thus interferes with the assimilation. As soon as that wonderfully adaptable mechanism, the human body, has recovered from its surprise at this new kind of food, it utilizes it in the same way as it previously consumed its ration of sugar. And here it may be added that the alcohol is burned in the tissues more rapidly when they are accustomed to it: the habitual user of alcohol is able to make use of its energy much more quickly than the abstainer. The moral for those proposing to draw a whisky ration instead of a sugar one would seem to be: "Drink deep or not at all from the alcohol spring". Unfortunately, while the utilization of alcohol by the individual is improved by consistent drinking, the utility of the individual to the community deteriorates in equal or in greater measure.

Alcohol is thus a food-stuff comparable to sugar

and bread-stuffs as far as the question of a supply of energy arises. It is not superior to these as a source of work and heat, and in practice is inferior to them in acting not only as a food but also as a drug or poison. The best food has no such further effects, but acts only as a means of supplying power.

The alcoholic beverages, however, have the advantage of being attractive to many people, and it may be claimed that this justifies their use, especially in these times when every substance should be used which can be utilized to keep up the national stock of energy. And if alcohol could be obtained from some plant or other source which could not be employed for other purposes, the argument would be a sound one. But, as is widely known, alcohol is obtained from certain cereals which might otherwise be utilized for food, and this changes the question from the abstract one to the very practical one whether the production of alcohol is the most economic way of using our limited supply of cereals. Even the strongest advocates of alcohol as a food would hesitate to put it before bread as a mainstay of life. We have therefore to consider whether in manufacturing alcohol we merely change the cereal which might be used for bread into an equivalent amount of energy in the form of alcohol, or whether there is an actual loss of energy in changing from cereals to alcohol. In order to ascertain this we have to make a somewhat extensive arithmetical calculation of the amount of energy contained in the original materials from which alcohol is formed, and to determine how much of that energy or fuel value could be utilized for food as bread and how much is actually utilized for food in the form of alcoholic beverages. The calculation is simplified by the fact that no potable spirit is being

manufactured at present, and we have only to consider the brewing industry.

I have found it impossible to make out exactly what quantities of beer were brewed last year and what it was brewed from, so that I have to take as the basis of my argument the beer production of 1916. This has been worked out by a Committee of the Royal Society, and I take my figures from them, so that they may be regarded as unbiased and accurate. In 1916, then, 26 million barrels of beer were produced in the United Kingdom, and the materials used were:

955,000	metric tons of	barley.
57,000	,,	grits.
120,000	,,	sugar.

In Table I, beginning on the left with these original materials, two alternative routes are indicated by the two arrows; the one leading finally to A indicates the use of these materials directly as food for man and animals; the other, leading to B, is the route that was actually followed, the materials having been used for brewing.

TABLE I

Original Materials.	Tons.		Food for Man.	Food for Cattle.
		↗	573,000 tons.	+ 382,000 tons (A).
			57,000 ,,	
Barley ...	955,000		120,000 ,,	
Grits ...	57,000		750,000 ,,	
Sugar ...	120,000			
	1,132,000	↘	26,000,000 barrels of beer.	+ 283,500 tons (B).

Let us first follow the A route, and consider the food value of these materials had they been consumed directly, without first being turned into beer and its by-products.

As regards the barley, some of you in your early enthusiasms may have investigated "barley meal" as a substitute for flour, and have quickly recoiled from it. You will therefore agree with the Royal Society Committee that only part of the barley can be used for human consumption. They estimate that 60 per cent of the barley, or rather over half, can be used for food. This is perhaps a low estimate. We have raised the percentage of wheat flour obtained from the grain from 70 to 80 per cent, and may go higher, and it seems probable that by careful milling at least 70 per cent might be extracted from barley. However, let us follow our authorities and take 60 per cent, or 573,000 tons, of flour as obtainable from barley. The whole of the grits may be used as food directly, making 630,000 tons of food from the cereals. As regards the sugar, I am in something of a difficulty, for it has been stated repeatedly in the House of Commons that this sugar is unfit for human consumption. I wonder if the Chancellor of the Exchequer has seen the "foot" sugar which was consumed by many of us last year, whether fit or unfit for human consumption. The Royal Society Committee tactfully avoids this point, and accepts the brewers' sugar as human food. And, in any case, whether it is fit for human consumption or not, this 120,000 tons of sugar occupies tonnage, and thus prevents the importation of other foods which are fit for human consumption, and which we need to import. The sugar must then be taken as a potential food for man, and that at its full face value.

In 1916, therefore, 750,000 tons of material which were available directly as human food were utilized to make beer. In addition, a certain amount of very highly cultivated soil was used to grow hops, which have no value as food; this soil could have been

utilized for potatoes or other crops. It is estimated that this land would have produced 150,000 tons of potatoes and 40,000 tons of oats. However, I do not propose to take this into consideration in my calculations; the case does not need it.

I have said that only 60 per cent of the barley can be used to make bread. The miller would not neglect the rest of it, however, but would use the 40 per cent remaining (382,000 metric tons) as food for animals, chiefly pigs.

Now we have considered the debit side of the ledger, what was expended from the general store of food in order to make drink. Let us next consider the credit side. What food value did we get in the form of beer, remembering that alcohol has food value, and that beer also contains a variety of starchy foods which have some value, although it is not very accurately known? I have grave doubts how far these starchy bodies can be utilized by the human body, but I give them their full value in the table to avoid fruitless discussions on a point on which nothing is definitely known. And again, I am not quite sure as to the amount of alcohol contained in the beer; it was said to be reduced from the former standard, but I cannot say how far this was the general practice nor in what proportion it was lowered. I have therefore taken 4.2 per cent of alcohol, which represents a fair average strength for the pre-war beer. About half the food value of beer is assigned to the alcohol it contains, the other half to the starchy substances.

In 1916, then, there were produced 26,000,000 barrels of beer, which, giving it the benefit of these doubts, had a considerable food value. Along with this there was formed in the process of brewing, as fodder for animals, 283,500 metric tons of dry material,

which was sold as malt, brewers' grains, and dry yeast. A good deal of discussion has been carried on in the Press as regards the amount of fodder obtained from the brewers; the discrepancies arise from some of the writers taking the weight of the brewers' grains in the wet state. This, of course, is quite wrong, as the value of the fodder depends only on the amount of solid matter, and not on the water it contains. It is clear at once that the amount of cattle food obtained from the brewer is considerably less than would have been produced if the materials had been sent to the miller. But this may be compensated by an increased value of the beer as food for man. In order to determine this, it is necessary to consider how far beer compares with bread as a food or energy-producer. When an engineer has to compare the value of two fuels, such as coal and oil, he determines how much heat a definite amount of each is capable of producing. This may also be done for the foods or fuels employed by the human machine, and all experience indicates that the results obtained by this method coincide with those obtained when the foods are actually consumed by man. In this way the beer and the original materials may each be assigned a definite numerical value in calories as producers of energy, and we may be confident that these represent their relative worth as sources of energy to man.

In Table II, the value of the quantities given in Table I is given in units of food (calories), and the same alternative routes are given: A represents the value of the food used directly for man and animals; B, that where it is formed into beer.

TABLE II.—FOOD VALUES IN UNITS (CALORIES).

Original Materials (millions of calories).	Food for Man (millions of calories).		Food for Animals (millions of calories).
3,981,000	2,651,000	+	1,330,000 (A).
	2,200,000	+	1,084,000 (B).
Difference (loss by brewing) ...	451,000	+	246,000 (A–B).
Loss per cent	17		18

The ingredients that could have been used as human food contained 2,651,000 millions of units, while the beer had 2,200,000 millions, or about 17 per cent less; that is, the route followed involved a loss of about one-sixth of the food value. For a rich and extravagant nation this is not very much, but in war-time it may deserve consideration. The food material lost here would have fed London, with its 7 millions of population, for more than three weeks. Along with this loss of human food there went an equal loss of fodder for animals. Here, again, about one-sixth of the value of the fodder which was originally available for animals disappeared in the processes of brewing. This loss of fodder, of course, entails a corresponding loss of fat or milk, and this indirectly again reduces the food-supply for man.

Another method of calculation gives even more striking results. I have spoken of food merely as the fuel for the engine, but food must also supply the wear and tear of the machine, and the value for this purpose of any food for the human body may be estimated by its content of the complex bodies known as proteins. In Table III I have therefore put down the amount of protein of the original materials and of the various products given in Table I, following the two alternative routes, the one (A) if the materials are

used for food directly, the other (B) if they are used for brewing. The sugar contains no protein, and is therefore omitted from the table.

TABLE III

	Protein of the Original Materials.	Protein of the Food for Man.	Protein of the Food for Cattle.
		48,000 tons. +	32,000 tons (A).
Barley	80,000 tons.	5,625 ,,	
Grits	5,625 ,,	53,625 ,,	
	85,625 ,,		
		4,250 ,, +	62,000 ,, (B).
Gain and loss		−49,375 ,,	+30,000 ,,

∴ Total loss of protein, 19,375 tons = 22½ per cent.

The barley flour and grits, which might be utilized as human food, contained 53,625 tons of protein; the beer obtained from these had only 4250 tons.[1] Over 90 per cent of the protein available for man is thus lost in the process of brewing. The protein fed to animals, on the other hand, is nearly doubled, and this might be regarded as compensating for the loss to man, since it may be recoverable from the animal in the form of milk. As a matter of fact, however, this recovery is very incomplete, and is quite inadequate to cover the loss; for the estimate is made that for the 62,000 tons of protein given to the cow, only 5170 tons are returned in the form of milk, so that, even taking this into account, the loss of protein to man by using food materials for brewing amounts to about 80 per cent. On another calculation, the total protein obtained for man and animals is less by 22½ per cent than if the materials had been used directly as food.

[1] The protein of beer is here taken at 0.1 per cent. Sharpe finds it vary in different beers from 0.038 to 0.185 per cent; this would give a protein content of the whole of the beer brewed in 1916 of 1600 and 8000 tons respectively.

It may be asked what becomes of the food thus lost in the course of beer-making. I have divided the original constituents between man and his friends the cow and the pig, the latter being only temporary reservoirs, and returning the food to man in the form of milk and bacon. When we use the grain for brewing, however, we have other claimants, and some of them are much more voracious than the pig even. In preparing malt the grain is allowed to begin to grow, and is then killed by heat, the object being to change the starch of the grain to a soluble sugar. This change entails the consumption of a certain amount of energy which is afforded from the original starch of the grain. Beer is then formed from the malt by the action of yeast which changes the sugar to alcohol. But the yeast plant can only grow and cause this change if it is fed abundantly, and it does this at the expense of the sugar obtained from the seed. We have thus two greedy mouths to feed in the formation of alcohol from grain: (1) the grain itself, and (2) the yeast plant. The food that remains after these have had their fill is consumed by man and cattle, but the food consumed in the process of malting and brewing would keep London for three weeks. There may be political or social reasons for feeding the yeast at the expense of the Londoner—of that I am not competent to judge—physiologically and economically it seems unjustifiable. It has been said of old that "It is not meet to take the children's bread and throw it unto the dogs", but we are throwing it, not to the friendly dog, but to organisms with which we can only become acquainted by the aid of the microscope.

Alcohol is not being distilled for use as a beverage at present, and I have therefore confined my remarks to the brewing industry. A few figures may be given

for the use of grain in distilleries, and I select the year 1907, the last complete year before the Commission on Whisky took evidence. The materials used were:

			Million calories.
Malt	173,000 tons	at 60% extraction =	870,000
Unmalted grain	247,000 ,,		
Molasses	50,000 ,,	= 12,000 tons sugar =	45,000
			915,000

The malt and grain, if milled to 60 per cent fineness, would have given flour equivalent to 870,000 million calories; assuming that the molasses contained about 25 per cent of sugar, a further number of calories would have been supplied to make a total of 915,000 millions. In the distilleries these yielded 91,000 tons of absolute alcohol, equivalent to 637,000 millions of calories. The loss in human food by the process was therefore about 30 per cent or 278,000 million calories, which is sufficient to feed London for thirteen days. The loss in food for animals is equally great when grain is sent to the distillery instead of to the mill. At present the distilleries are providing only industrial spirit for the manufacture of munitions, and we have no indication how much grain which might be used as food is being employed in this way. It has been suggested that the large stocks of spirits in bond might be redistilled and utilized for munition purposes, thus freeing a certain amount of imported grain for food. This drastic proposal could only be carried out at a cost of many millions, as the whisky would have to be paid for; and it is to be hoped that we shall not be driven to straits which would make the suggestion a question of practical politics.

Besides the financial objection, it is urged that distillation must be continued in order to produce yeast

for bread-making, which in many parts of the country is entirely dependent on the distillery product. About twenty distilleries were engaged in yeast production in 1907, and some of them turned out as much as 30 to 40 tons of yeast per week at £30 to £40 per ton. In these the alcohol had almost become a by-product. But is yeast in this amount necessary for bread-making? There seems no question that of late years the baker has been extravagant in his use of yeast, and that equally good bread can be baked with a much smaller supply. And in many parts of Scotland and the North of England the bakers do not depend on distillery yeast at all. If the prejudices of the bakers against a departure from a luxurious method can be overcome, there seems no reason why the distilleries should not be shut down and the present stock of spirits drawn on for industrial purposes. A certain amount of grain would thus be freed for consumption. But for financial reasons this could only be done as a last resource, to which it may be hoped the country may not have to resort.

The discussion of the food value of alcohol and beer at such length has left but little time for other beverages, but their importance as foods is comparatively small. Tea and coffee as such have practically no value in themselves as foods. Those ascetic and rather superior persons who drink tea or coffee without milk or sugar, obtain no food from them, and I am afraid must be classified among drug takers, for the only constituent worth mentioning is caffeine, which stimulates the brain and rouses to wakefulness and relieves fatigue. On the other hand, the addition of sugar or milk or cream gives some value to these beverages. In the days of abundance before the war I had once the curiosity to estimate the food value of the sugar taken in coffee by one individual, who, I

must confess, drinks it very sweet. I was surprised to find that his coffee had the same food value as ordinary beer. The sugar added gave as much energy as the alcohol of the beer. Where milk is added in addition to sugar, as is still the general custom, coffee and tea may have quite a high food value—greater than that of the strongest ales.

Cocoa differs from tea and coffee in containing a considerable amount of fat, protein, and carbohydrate. A cup of cocoa made with water may be estimated to have about half the food value of an equal amount of beer. If made with milk the value of cocoa is multiplied about four times.

Most of the other beverages hardly have any value at all as foods. The sweet effervescent drinks may contain sugar in trifling amounts but very often contain only saccharine, which is valueless as food.

A. R. C.

The Strategy of

FARMING, PAST AND FUTURE

The events of the last three years have, to a considerable extent, if tardily, drawn people's attention to the fact that they are dependent upon agriculture for much the larger part of their food, but I very much doubt whether the majority of people realize how great a fight has to be waged before the farmer can win food from the land in sufficient quantity to meet the demands of a district that is at all closely populated.

May I for a few moments draw your attention to the elements of the fight? In daylight we find ourselves moving in and surrounded by the rays of the sun, which form the motive power of the process of food production; we have underfoot the land, which is the laboratory *cum* manufactory capable of using this motive power in such a way as to promote full plant growth. There are two great armies wishing to secure the services of the sun's rays and of the land, namely, certain plants and man. These plants have the natural desire to live, to reproduce themselves, and, when dying, to leave all they possess to their heirs. It is a fact that all they have to leave is strictly limited to their own dead bodies; but that is not their fault, and it happens that this residuary gift is of such great value to their descendants that it quite satisfies their wants. Man, on the other hand, wishes to secure

the plant or its offspring, or both, for his own maintenance, reproduction, and bequeathment. Sometimes the human being is so kindly as to allow the use of the conquered—the plant—to some animal, but even then, more especially in the case of farm live stock, he has the ulterior motive of self-preservation or of gaining for himself greater ease. This struggle between man and plant may be roughly divided into three stages, all more or less coinciding with various stages in our civilization. The most primitive consists in a kind of war carried on by a small number of men among an innumerable host of indigenous plants, these few selecting victims here and there on which to prey. Children blackberrying, schoolboys nutting, or their elders truffle-hunting among the beech woods, are among the more elementary examples of this guerrilla warfare; or again this type of war is exemplified by the doings of those picturesque individuals called, in different parts of the world, "ranchmen", "cowboys", or "bushmen", who control vast herds of cattle or sheep on large areas of the little-inhabited parts of the earth's surface.

A further advance in the evolution of strife consists in the wholesale destruction of living plants to enable man to rob from their offspring the residue left for them in the land by numberless generations of forebears. This second stage is well exemplified by the husbandmen of the prairies, whose exploitation of the "virgin" soils of the world is well known to you all. This enterprise is a certain advance in the science of this class of war, it requires some material, a certain amount of preconceived plan, and some systematic endeavour to ensure success. As in the first case, however, its essence likewise consists of theft carried out against plants indigenous to a district, and, the booty once secured, man's rôle is one of retirement,

leaving the enemy in possession and master once again of his own domain. The difference is one of degree: in the first instance the ravages of the human host only entail partial destruction of the plant populace occupying the country. The blackberries, nuts, or grasses are not captured or destroyed in large enough proportion to exterminate even temporarily the adult population. In the second case the adult population is as far as possible temporarily exterminated; it is through their offspring, known to us as seed, that repopulation proves possible.

The third and much the more advanced class of warfare—farming proper—consists in eradicating the plant enemy known as the weed, and occupying the land in perpetuity. This involves many things, among which may be mentioned the thorough working of the land with tillage implements, the supply of manures, and the selection of the seed of friendly plants—farm crops—which will better supply man's wants than the supplanted vegetation, and, besides all this, many things costing labour, money, and skill. And all the time man is putting his capital and brain work into the production of his own farm crop, the enemy must be kept at bay. Total extermination is not attainable, nature sees to it that an innumerable host of weeds is always present to attack the husbandman, and, if his efforts are inadequate, to regain the land and the motive power from the sun for themselves and their offspring.

There are then three possible policies: pilfering, theft, and production, and the strategy of farming, to my mind, consists of deciding which of the three a nation is to practise.

My submission to you to-night is that in the past this country, in which we live, decided between the years 1850 and 1875, for good or for evil, to go in for

theft to the neglect of production. That the form of strategy fixed upon was not deliberately chosen I am quite aware. The great reformer, Cobden, who played so large a part in leading national thought when the policy was decided upon, if I read correctly his essays and speeches, had no such wish. He was at much pains to explain how the land might be made more productive if his theories were put into practice. He wished, and not without reason, that the value of land, as expressed in rent, might be less high in the second than it had been in the first half of last century; above all, he intended that the terrible lot of the agricultural labourer should be improved. In paying my humble tribute to the splendid effort Richard Cobden made on behalf of this class of the community, I would submit that it was the treatment that the rank and file of the agricultural army received during the first half of the nineteenth century that brought down the judgment of God upon the industry as a whole. Cobden had no conception[1] that the system he advocated would cause much of the land in England to come down to prairie value. He relied, moreover, upon the cost of transit[2] of food to protect the farmer from competition with produce stolen from the virgin soils of the world overseas, but between 1875 and 1885 that safeguard practically disappeared. The ten shillings a quarter he foresaw as the perpetual shield against the ruin of the industry, fell to a sum closely approximating to tenpence, with the result that this country revelled in a supply of cheap stolen goods which she soon learnt to appreciate at the worth of the low price she paid for them rather than at their intrinsic value of life-keeping food.

We must now review the effect of the sale of almost

[1] *Speeches by Richard Cobden, M.P.*, Vol. I, p. 52. Edited by John Bright and J. E. Thorold Rogers. Macmillan & Co. [2] *Loc. cit.*

unlimited supplies of stolen food upon the agricultural industry, or rather upon the farmers—the captains of industry of agriculture.

Those who suffered may, as far as I am able to judge, be divided roughly into three classes.

The first class, by the accident of holding exceptionally good land, by the accident of farming in a particularly favoured situation, or by that competence which enabled the superman to combine the knowledge of the scientist with all the characteristics of a first-class captain of industry, *carried on* in spite of the flooding of the markets, on which they had to sell their goods, with produce the result of theft. An audience such as this will realize that the number who could so carry on was very limited.

The second and much larger class themselves turned land-robbers to a greater or less degree. It was not merely that four millions out of sixteen millions of acres of arable land was lost to the plough in England, but the whole level of production had to be reduced. No farmer can complain at having to compete with farmers, but when it comes to competition with men who have no rent, no manures, no rates and taxes, and very little labour indeed to pay for, it is a different question altogether. Scratch part of the surface of a vast prairie, take a crop of wheat grown on the fertility which the dead bodies of countless generations of weeds have accumulated for their offspring, and then move on to do the same elsewhere, and you have too cheap a form of production for the average farmer to compete with. He has to work the soil deeply, manure it, often drain it, so that the air, water, and the great motive power of the world—the sun's rays—may help his crop to such a good start in life that the roots of the bread-winning plants may search deep into the subsoil. There they will find

material with which to manufacture food, which the human race in a thickly populated area must have created in great abundance if it is to carry on.

A third class, who are of the utmost importance to our analysis of the past, remains to be considered. These were they who in striving to remain in the first class failed and *fell by the way*. Their sad story has had a very deterrent effect upon food production in England during the first years of the present century. For many reasons prices improved after 1900 had passed, but farmers could not forget the story of those who fell in the cruel and unequal struggles of the late 'seventies, and the terrible farming years of the 'eighties and even the 'nineties.

Further, "good times", due no doubt partially to the cheapness of food in our cities, drew away from the country the more intelligent and the men of best physical development from among the agricultural labourers. Again, in many districts the times, though improved, were not good enough to allow of adequate wages being offered by all those wishing to farm once again. I am not here to defend those agriculturists who took advantage of this dearth of competition to secure for themselves good labour for an inadequate wage, for I know only too well that they are without excuse, and I know that their conduct is to a certain extent responsible for the slowness of the revival of universal farming in England. I can, however, assert that in the great majority of cases the wages paid, poor as they may have been, were as high as the employer could afford, and, again, often quite adequate remuneration for the class of service rendered: for the constant withdrawal of the best men from the land had led to a marked reduction in the worth of the labour that those who remained could, or would, in return, give for their wage.

May I remind you of another thing that Cobden, and those reformers who worked with him, did not foresee, namely, the necessity of ensuring that the supply of home-grown food during the continuance of a world war should be as great as can reasonably be secured?

May we not with advantage think of this last point when we are discussing the strategy of the future? Does any reasonable man now doubt that in these islands it is unwise to neglect to support agriculture in times of peace? If such a person is among this audience, I must leave him to his own reflection, for I have only too little time left in which to draw your attention to such considerations.

I believe, and I think it is fortunate that it should be so, that the nation will have ample time in which to reflect upon the problems involved, for in my opinion, for some years after the war is over, the world will have to *stop thieving* from the land, and farming will have to become universal.

I maintain, however, that it is wise to look forward to the future, which may bring a time when Britain is once again offered produce stolen in large quantities from the soil. It is my ambition that by then this country may have learnt to see the evil of handicapping home agriculture, and it will, I hope, have devised some scheme which will have the effect of subsidizing home production.

As regards her methods in the immediate past of handicapping agriculture, may I start by speaking of the subject nearest my heart—education? At present in our elementary rural schools all the thoughts of many of the teachers are turned towards the hopes of better pay *in the towns*. Can it be hoped that such terms of employment will lead to any *enthusiasm* for the romance of the art of food production being active

in the minds of those who teach our little children in our English village schools? No one who has studied the agricultural problem, as well as that of education, needs to be told what a handicap an absence of such enthusiasm must be to the farmer who requires a proper proportion of the village children to grow up into a population that will supply good men to work his land.

Turn from the peasant to the proprietor, and realize the lack of adequate instruction for the landlord class at many of our universities.

In England, Ireland, Scotland, and Wales, from the hundred years succeeding the French Revolution, our splendid class of young landlords, who have so freely given of their best in this war, were taught, with exceptions so small as to be negligible, every business under the sun except their own. On the other hand, Napoleon established at Versailles for French agriculturists one of the finest agricultural colleges the world has known, as soon as ever his despotism created order out of the chaos the revolution had made. Even now one is constrained to be thankful that the effort made to educate the landlord is not so small as it was twenty years ago.

There is also the question of local taxation to be revised. It is hard on the agricultural community that the holes in country roads torn up by motors flying out from the towns should be repaired to some extent at their expense. Our system of local taxation not only inflicts such a hardship on the farmers themselves, but also imposes a greater handicap still on home production: for if a man lets his farm go derelict, his share of such a tax will be low; if he carries on intensive cultivation, and induces his land to produce the utmost, his share will be high.

In the days before the war a landlord might have

wished to increase production by turning grass-land over with the plough, and this, besides reducing the rent he received, involved putting up farm buildings at considerable capital outlay. Parliament, as an act of common justice, had remitted half the charge for local taxes *on the land*, but new buildings constructed for increased food production would have had to carry their whole share, for, unlike the land, the buildings of the farm receive no reduction. The ill effect of such a system of taxation must strike anyone who reflects for an instant. Grass-land farms, with their higher letting value, require little capital outlay on buildings, few of which are required for this class of husbandry. The local taxes on land are halved, but the rates on buildings are left by our countrymen at their old high level. Was this system not likely to prevent grass-land being brought back to the plough? For under it a landlord, by putting his capital into buildings and having his meadows and pastures ploughed up, could only expect a reduction of rent; the farmer taking the plough-land farm could only expect his local taxes to be higher. Does my audience wonder that those of us who for some years have been preaching a *return-to-the-plough* sermon have had to be content with apathetic congregations? And yet, as regards production, the plough-land will always be the greater national asset: every authority knows that arable land yields more produce than permanent grass. The whole question would require more time than I can give it, even had I, which I have not, the expert knowledge with which to bring it in detail to your notice, but I have knowledge enough to tell you briefly that, as regards local taxation, the strategy of the future must be guided by ideals of increased production rather than by visions of vote-catching among the dwellers in the towns.

It is admirable that municipal government should have splendid systems of tramways to convey the tired workmen from the factories to their homes in the suburbs, but that is no reason why we should be practically without any systems of light railways to bring the bulky produce of farmers working in remote districts from the land into the town. Are the British public aware that it used often to cost more to send 500 pounds of bread-stuff from one part of an English county to another than it used to cost to send it from the plains of the Old World to the big ports of our island home? If they know it, do they realize what it means? I hear to-day people talking of the wickedness of farmers feeding barley meal to their pigs. I shall, if I live till December, have been lecturing to farmers and agricultural students for twenty years. For the first five years of that time it was my duty to tell farmers *how foolish it was of them not to feed their wheat to swine.* Wheat, which then was round about 25*s*. for 500 pounds, cost so large a proportion of its value to deliver that it was the right policy to let it go to market in the concentrated form of pork.

I could keep you here all night talking of our grievances, but let me now turn to two suggested remedies that loom large in the mind of strategists thinking of the future, i.e. small-holdings and industrial farms.

I will begin by saying we must, in any perfect system of national agriculture, have enough small-holdings to fulfil certain demands.

There is, first of all, the local need of a small farmer to supply such things as milk, eggs, vegetables, &c., to a small village community. Such men must be encouraged more and more, and not suppressed, as was often the case before the Small Holdings Act was passed.

Again, there is among us a certain class of men who work very much better as their own masters (or slaves) than as someone else's men, and yet have not the gift to command others. These are sufficiently numerous for it to be wise of us to cater for them; it is, I believe, imperative to do so if individuality—one of the greatest of our countrymen's gifts—is not to be driven out of the agricultural labouring class. The pity of it is that in the past so little discrimination has been shown, when letting small-holdings, between the class of man I have tried to describe and the man who wants a holding of his own *because he does not want to work either as master or man!*

Again, it would seem that certain localities are so favourable to spade- as against plough-husbandry as to let small-holdings come naturally: these, I need hardly say, I should not suggest disturbing.

But over and above all, we must have enough small-holdings *to let our good men get through and become masters.* Many such potential captains of industry would be kept back had they to wait till they had saved out of their wages enough capital to take a large farm. The great army of agriculture cannot afford to risk losing its best "rankers", and to my mind an adequate supply of small-holdings is necessary as a training school and as a step-ladder.

The foreman, head wagoner, cow-man, shepherd, &c., on large farms would be more likely to give good service to their masters if they all felt that the possibility of securing a holding of their own was a matter of practical politics. Many would never take advantage of the possibilities, but some would do so, and remain useful small-holders all their lives. One can, however, confidently foresee that among those who start the best would get on, and become recruits for the class of really useful large farmers who are

not now plentiful enough to secure for the nation the utmost agricultural output.

These few classes of men would, however, never be likely to absorb more than a small proportion of our land. Any attempt to force all our country under the Small Holdings Act is foredoomed to failure. It is, to exemplify, like what reverting to the days of the handloom in the textile industry would be. A small-holding, *per se*, is intrinsically economically unsound. The proportion of waste land is increased, the accommodation of the farm-buildings and of house room is proportionately reduced, and the capital outlay on implements of tillage is proportionately increased. Waste of material, such as the trimmings of corn-stacks and outsides of hayricks, is quite needlessly increased. Above all, the skill of the men working such small units of land single-handed, is diffused over so many classes of work as to lower the performance of nearly every operation carried out to the level of work done by the apprentice. At best, as on large farms, the skill of the men employed must be very varied, but on the large holding it is possible to select, and so to put the best thatcher on to thatching, the best "builder" on to stack-building, the best horseman on to control the more difficult colts, the best machinery man on to the more complicated implements, like the self-binder, &c. On the other hand, the small-holder has to do everything, regardless of his ability in one particular direction. The policy of establishing all our land as small-holders' farms is such poor strategy, that it only wants some little knowledge and enough consideration to ensure the country's rejection of the plan.

The "industrial farm" has much more to recommend it; on paper the "small-holding" has not a look in. The theory which establishes the perfection

of the former, however, assumes too much—much too much in my opinion. The work of the intensive farmer cannot properly be compared with the avocation of the manufacturer. The man who has to produce the utmost from each of his fields has to have a special knowledge of each of these divisions of land, and, what is more, has to impress his own individuality, to a certain extent, on each of the men who are working, *separately*, or at any rate in small parties, all over the land. The thing is quite as special as, say, dentistry. False teeth may, we believe, be manufactured by the pound, yet it is customary, and I think it is likely that it will remain customary, to look upon the dentist as a professional man. The dentist has to combine knowledge of his individual patient with his general medical and engineering ability, and crown all three with manipulative skill. So with the large farmer; he requires the knowledge of a collection of subjects, forming a conglomerate of learning at least equivalent to that required from many men of high professional standing. Yet, with all this, his capacity as a man of business must be great enough to bind all his mental faculties into one definite weapon of attack against his weed enemies. And, while he is so fighting to conquer them, he must further contrive to induce the great forces of nature to produce his own and his fellows' food to the greatest possible amount; for if he does less he cannot be said to carry on *intensive farming*. When all this is realized an industrial farm of 5000 acres, pushed to produce its utmost, seems quite beyond the capacity of any but the very exceptional man.

The physical limitation of the ordinary man alone seems to make the enterprise impossible. In this small island country of ours it cannot be expected that such a farm would consist of less than 125 fields.

That is to say, it would have fields of an average size of 40 acres. These seem to me to be the largest that can be reasonably thought of when allowance is made for the crumpled formation of our geology and the ever-varying nature of our climate. Think how far would a man have to walk to get over such a farm! I cannot think but that he would have to traverse each field *on an average* once every working day of the year. That is to say, he would have to walk over 30 miles on each of six days in the week in order properly to supervise the working, grazing, and folding of the land. This amount of exercise obviously would be impossible, and so much of his work would have to be deputed, and it is this transference of authority which destroys that individual capacity which alone can induce each field to produce its utmost. In the past one has seen examples of men enlarging their occupation of land by piling farm upon farm, each holding being under the immediate supervision of a bailiff, foreman, or manager, some deputy of the master by whatever name he was called. Such have been among the very worst examples of land robbers! Why then seek to encourage them under the name of industrial farmers? These gentlemen farming large areas (and even for such work 5000 acres were very exceptionally high), made very small profits indeed out of each hundred acres; they relied entirely on the quantity of land held to atone for smallness of yield from individual fields. In their own way they were capable, enterprising, and hard working. *Had it been possible* they would, I contend, have farmed intensively, or produced the utmost the land was capable of yielding, whereas it is common knowledge that they did no such thing, but very much the reverse.

I have had considerable experience of the farming

community. I have had about 700 long-course students under my instruction in husbandry; I have known, intimately enough to judge their capabilities, quite another 500 gentlemen farming our land, yet I cannot, after careful thought, bring to mind a dozen men capable of running an "industrial farm" of 5000 acres in such a way that every field should be doing its fair quota towards feeding this very thickly populated country of ours. It takes an exceptionally good man to farm 1000 acres thoroughly; 500 intensively done is quite enough for the man usually spoken of as just above the average.

It is to these latter that I look to for help in the future. The strategy should be to train such men so that they take full advantage of co-operation. They must learn to take advantage of all the experience of the past—which includes avoiding the errors of the past—to supervise science in such a way that agriculture may derive the fullest possible benefit from research; and also to be ready to criticize, without carping at, all that systematic investigation lays before the farmer. Further, they must learn—all the better if self-taught—to co-operate as regards the use of labour-saving machinery, such as traction steam tackle, motor-ploughs, threshing-engines, and the like. They must also learn to be more careful as regards studying the markets, account-keeping, saving unnecessary losses, and reducing all excessive middlemen's profits. Last, but not least, they must learn to know their fellow men, so that, on the one hand, they may make good tenants themselves, and so bring more capital on to the land, while, on the other hand, they may secure for their own advantage the services of a devoted peasantry working to their own satisfaction for the furtherance of the greatest possible home production.

But none of this is at all likely to come about if the British public is not willing to give the agricultural industry security for the future. I say for the future advisedly, as for the present, and for some years after this war, the world has got to farm hard, or the world will starve! I have not met any authority of any weight who thinks it possible that land robbery can start immediately the war is over. We all, farmers, landlords, labourers, as well as experts, are, however, looking to the time when *stolen produce* is offered once again to this country. That is the only danger we want protection against. The question as to what form that protection is to take is, I submit, worthy of the consideration of all thinking men.

For myself I suggest that it is worth this country's while to think out some plan that will for the future *subsidize production*. The capitalist—in other words the landlord—the captain of industry—you know him as the farmer—and the greatest national asset of them all — the agricultural labourer — somehow or other have to be convinced that you do not intend to let them down once again in the near future as you did between 1875 and 1900. Convince all three parties of this, and your insurance premium against the risk of your once again finding yourselves in the dangerous position you are in now is receipted. Let these three classes go on believing that you are only anxious for the time when you may once again have food cheap enough to waste to your heart's content, and you will be as far off reliance on home production in the future as you were in the August of 1914.

How best to subsidize production is a problem so difficult as to entail a study that any peaceful strategist, however brilliant, may find worthy of his talents. Nevertheless, I am venturing to conclude my lecture by putting before you my own ideas as to a solution.

I will begin by asking you, for the sake of your country, to forget that the questions of Free Trade and of Tariff Reform were ever torn to pieces by the wolves of party politics; or rather, shall I say, may I ask you to realize that, owing to the stress of war, these nauseous subjects have been masticated, swallowed and digested. We have to look at the problem with eyes recently recovered from blindness.

I suggest to you that all food should bear the cost of its own police protection. You ask a British farmer to pay rates so that the police may protect his produce; let the overseas food pay for the navy that is there to protect it. Cobden, in his early days,[1] saw no harm in a fiscal duty on food. I suggest to you there is good in such a system of taxation. In the first place, such a system of taxation might be well used to check all tendency to waste; further, I should use it as a means of encouraging home-grown produce.

I would begin by coming to an understanding with the landlord or the capitalist. To these I would say: "Our scheme of taxation will, if by the wit of man it can be accomplished, insure you decent rent for, or interest on, the value of every acre you possess so long as it is intensively farmed. The same principle will apply to any buildings you may put up or any improvements you may execute that will help on production to the utmost. But, on the other hand, if you want to own land so as to allow yourself the pleasure of entertaining your friends to great slaughters of hand-reared pheasants, or so as to enable you to surround yourself with incompetent tenants who pay you part of their rent in servility or for any other sort or kind of amenity, why then we have to tax your land

[1] *The Political Writings of Richard Cobden*, Vol. I, p. 149. Published by William Ridgway, 169 Piccadilly, W., 1868.

at least to as great an extent and in the same proportion as the champagne people drink, or the powdered footman they employ, or, in fact, as, high as we would *any other extravagant luxury*. It is indeed hoped that we may be able to apply taxation so high that you will give up misusing the nation's most precious commodity, and spend your surplus wealth on some other form of amusement."

Turning to the farmer, I would remind him that all food wherever produced was to pay a substantial fiscal duty. Such duty would pay its proper share of the cost of the navy kept up to police our trade routes, and also of the army necessary to ensure that we should not again find ourselves in the precarious position in which we did in the year 1917 owing to our inability to prevent our enemy from constructing U boats on land quite close to our shores. I would arrange that the farmer paid such taxes on all his produce, it being understood, for it is only fair, that in assessing him his local taxation should be considered. This taxation on home-grown food could then be remitted, and it is part of my scheme to do so, under all or any of the following conditions. Firstly, if there be danger of the prices of incoming food stolen from virgin soil going so low as to penalize *intensive* home production. Secondly, if there were danger of prices getting so low as to prevent all farmers paying their labourers a wage high enough to ensure the country's having an adequate rural population. The paying of a satisfactory wage to good men would always be an imperative condition of any remission of taxation on home-grown produce. Or again, if for purposes of insurance against any particular national danger or disadvantage it was desired to encourage any particular form of production, such as that of wheat, or wool, or some class of

meat or dairy produce, a remission of taxation on that crop or product might be granted.

The *essence*, however, of my whole scheme is that under no conditions whatever should remission be obtained by the land-robber. To remit the food-tax to the land-thief means giving profit to the individual at the expense of the nation's wealth. To remit to the *intensive farmer* is my idea of the best way to subsidize production.

Any such scheme involves the setting up of some form of authority to decide which estate is well or ill managed, which farmer is paying a living wage, what is intensive farming, &c. I admit this to be a disadvantage, but, I contend, it is less of a disadvantage than to go on with a very large proportion of this land of ours not properly farmed. I confess I would rather have the trammellings of a Department of Lands and a Land Court with its many possibilities of evil than run the risk of not getting every acre we possess once again under conditions of high fertility.

Anyhow, I am convinced that if we are to be warned by the past, it is necessary that future policy should on the one hand deal out greater fairness to the landlords and the farmers, and, on the other, insure by every and any reasonable means that agriculturists themselves do their duty in winning food in the greatest possible profusion from the land of England.

K. J. J. M.

The Possibilities of Increased CROP PRODUCTION

From the earliest dawn of history men and women have studied the possibilities of crop production, but the subject has never been of more importance than it is at the present time, when the world's supplies of food are falling, and the efforts of a considerable part of the human race are bent on destroying the stock that is left. Unless we can somehow increase our crop production, we, our children, and our civilization run a lively risk of being overwhelmed in disaster.

Although the problem is an old one, its present-day aspects have many new features. Under old peace-time conditions the farm, like any other business concern, was run frankly for profit, and the standard for measuring a man's success or failure was simply the amount of profit obtained per acre. Under present-day conditions, however, the standard is wholly different: it is now the amount of human food per acre that matters—calories instead of pounds, shillings, and pence have become the standard. And although it is admittedly difficult to change horses while crossing a stream, the patriotism and good sense of the farmer have enabled him to make the change in outlook, which is steadily being followed by changes in methods. Our recent meat troubles remind us that we shall involve ourselves in disaster if we make food production actually unprofitable; but

so long as the danger lasts we may rely on the farmer not to put profit before food, but to raise as much food as possible.

In the old days British fiscal and social conditions made it more profitable to grow food for animals than for men. Out of 46¾ million acres of land in cultivation in the United Kingdom only about 5 millions directly produced human food and nearly 42 millions produced animal food — no less than 34 millions being grass.

Our food-supply during the five years preceding the war (1909–13) was as follows:—

FOOD OF THE UNITED KINGDOM: MILLION TONS PER ANNUM

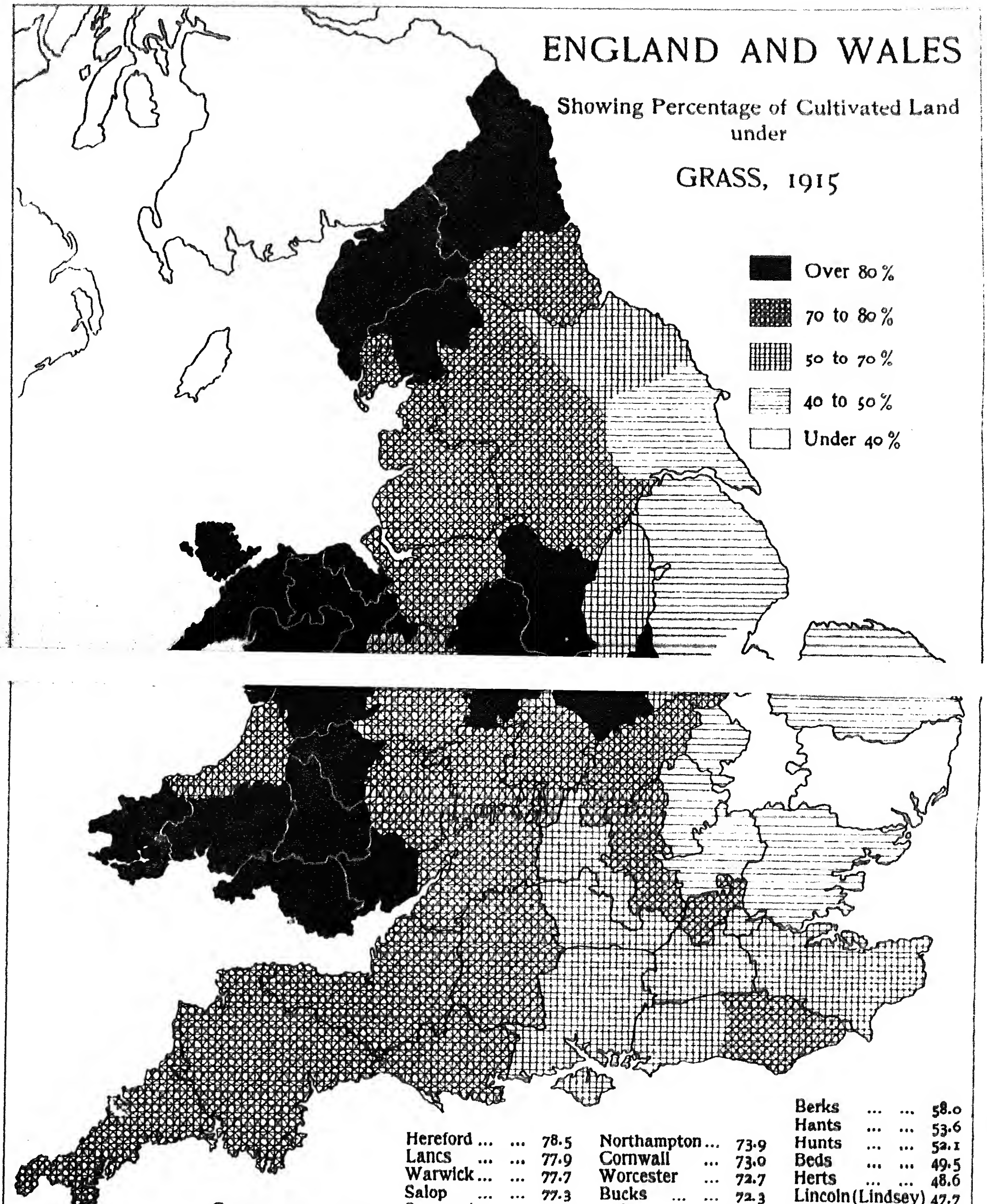
	Quantity Obtained.			How Utilized.	
	Home Grown.	Imported.	Total.	Eaten by Human Beings.	Eaten by Animals.
Cereals	6·5	10·4	16·9	5·2	9·2
Potatoes, &c.	4·8	·7	5·5	4·5	1·0
Other roots (estimated)	44·5		44·5		44·5
Grass (estimated as hay)	60·0		60·0		60·0
Other foods:					
Sugar, fish, &c. ...			3·4	3·4	
Cake, straw, &c. ...			6·3		6·3
Animal food:					
Dairy produce (mainly milk) ...	4·7	·5	5·2	5·2	
Meat	1·8	1·2	3·0	3·0	
Total	122·3	12·8	144·8	21·3	121·0

Thus we obtained from all sources 120 million tons of animal food, most of which was grown at home, and a little over 22 million tons of human food, more than half of which was imported.

ENGLAND AND WALES

Showing Percentage of Cultivated Land under

GRASS, 1915



County	%
Monmouth ...	90.3
Merioneth ...	89.1
Brecknock ...	88.7
Glamorgan ...	88.3
Carmarthen ...	88.0
Westmorland ..	86.9
Derby	86.7
Radnor	85.8
Carnarvon ...	85.6
Montgomery ...	84.4
Leicester ...	83.5
Northumberland	83.0
Flint...	81.8
Staffs	80.9
Pembs	80.7
Denbigh	80.7
Anglesey ...	80.7
Cumberland ...	80.2
Hereford	78.5
Lancs	77.9
Warwick... ...	77.7
Salop	77.3
Somerset... ...	77.3
Sussex (E.) ...	77.1
Cardigan ...	76.5
Gloucester ...	76.0
Cheshire... ...	75.8
Yorks (W. Riding)	75.7
Durham	75.6
Dorset	74.7
Devon	74.2
Middlesex ...	73.9
Northampton...	73.9
Cornwall ...	73.0
Worcester ...	72.7
Bucks	72.3
Wilts	71.3
Yorks (N. Riding)	69.9
London	69.5
Rutland	69.0
Surrey	68.1
I. of Wight ...	65.7
Kent	63.8
Sussex (W.) ..	62.4
Oxford	60.8
Notts	60.4
Berks	58.0
Hants	53.6
Hunts	52.1
Beds	49.5
Herts	48.6
Lincoln (Lindsey)	47.7
Yorks (E. Riding)	46.7
Lincoln (Kesteven) ...	46.6
Essex	43.8
Norfolk	40.7
Suffolk (E.) ...	36.9
Cambridge ...	34.7
Suffolk (W.) ...	33.3
Lincoln (Holland)	32.1
I. of Ely	27.0

Figures taken from "Agricultural Statistics", 1915, Vol. L, pt. 1.

The common statement that in the old days we only grew half our food is therefore perfectly correct, but it ought to be qualified by the further statement that we grew ten times as much animal food as human food. The farmer obtained his profit, but it cannot be said that the nation obtained much food: the 120 million tons of animal food gave us a certain amount of energy, a certain amount of pleasure, less than 2 million tons of meat, and less than 5 million tons of dairy produce—mainly milk. But under the old conditions the system worked; it gave the greatest satisfaction to the greatest number, and so it survived.

In our present circumstances it is not profit but *calories* that have to be considered. On this basis the crops come out as follows:—

HUMAN FOOD PRODUCED PER ACRE OF CROP, 1909–13

	Yield in Tons (less seed). Great Britain.		Energy Value of Food (millions of calories).[1]		Number of Days for which One Acre will provide for One Man.[2]
	Crop.	Flour.	Per Ton.	Per Acre.	
Potatoes	5·4	—	0·96	5·16	1500
Wheat	·80	·64	3·7	2·38	700
Barley	·72	·43	3·9	1·68	490
Oats	·62	·41	3·9	1·60	470
Meat from:	lb.				
Rich pasture ...	190 fat meat.[3]		5·66	·49	140
Medium pasture ...	100 lean meat.		2·96	·13	40
Poor pasture ...	20 lean meat.		2·29	·02	6
Milk from good grass ...	2000 milk. 45 meat.		·74	·67	200

[1] From *Royal Society's Committee Report*, Cd. 8, 421.

[2] Assuming 3400 calories needed for one day.

[3] Weights of meat and composition of fat meat, taken from Sir T. H. Middleton's paper, *J. Bd. Agric.*, September, 1915.

Measured by the standard of calories, potatoes are the most valuable of the crops commonly grown and grass-land by far the least.

Food production and crop production over the whole farm, and therefore over the whole country, can be considerably increased by changing some of the grass-land into potato- and corn-land. The problems involved are largely those of administration and organization, and, in spite of difficulties, they are being solved. At a time when production all over the world is going down, we have not only avoided a falling off, but have actually increased our production in spite of bad seasons, labour difficulties, and the spread of weeds. The results for England and Wales have been as follows:—

AGRICULTURAL PRODUCE IN ENGLAND AND WALES

(In millions—qrs. and tons.)

Crop.	Peace Time—Average of 1911, '12, '13.		War Time—Average of 1915, '16, '17.	
	million qrs.	million tons.	million qrs.	million tons.
Wheat	6·9	1·5	7·5	1·7
Barley	5·8	1·1	5·1	1·0
Oats	9·5	1·3	10·6	1·5
Total	22·2	3·9	23·2	4·2
Potatoes	—	2·7	—	2·9
Mangolds	—	7·9	—	7·9
Hay (all kinds) ...	—	7·8	—	7·7

Nor is this all. During the spring of 1917 no less than 278,000 acres of grass-land have been broken up and converted into arable land, and the ploughing programme is being greatly extended during the present year, so that we may reasonably hope for

a still further increase of food production in the near future.[1]

There is a second direction in which increase of crop production is possible. The yield obtained by ordinary farmers is a long way below that obtained by the best farmers, as is shown in the following table:—

PRODUCE OF CROPS IN ENGLAND AND WALES

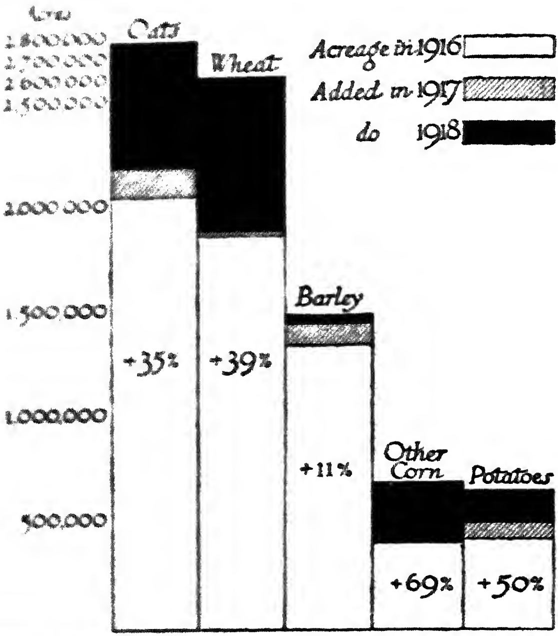
Crops	Average Yield per Acre for Ten Years. (1904-13).	Yield expected by Good Farmers.
	Bushels.	Bushels.
Wheat	31.7	40 to 50
Barley...	33.3	40 to 60
Oats	39.5	60 to 80
	Tons.	Tons.
Potatoes	6.2	8 to 10
Mangolds	19.5	25 to 40
Swedes	14.2	12 to 15 in southern counties 20 to 30 in northern counties

Several factors are involved: the best farmer has, of course, a much better knowledge of crops and of soil management than the ordinary farmer, and also he has usually managed—and quite rightly—to take possession of the best types of soil. It is a commonplace that high-rented land is well farmed, while low-rented land is badly farmed. There may be a slight causal connection between these factors: a man may work harder when he has to pay more rent, and slacken his efforts when his rent is lowered. But, in the main, the high rent and the good farming both arise from the circumstance that the land is good,

[1] The Report of the Director-General of Food Production up to 1st June, 1918, shows how much was achieved in this direction.

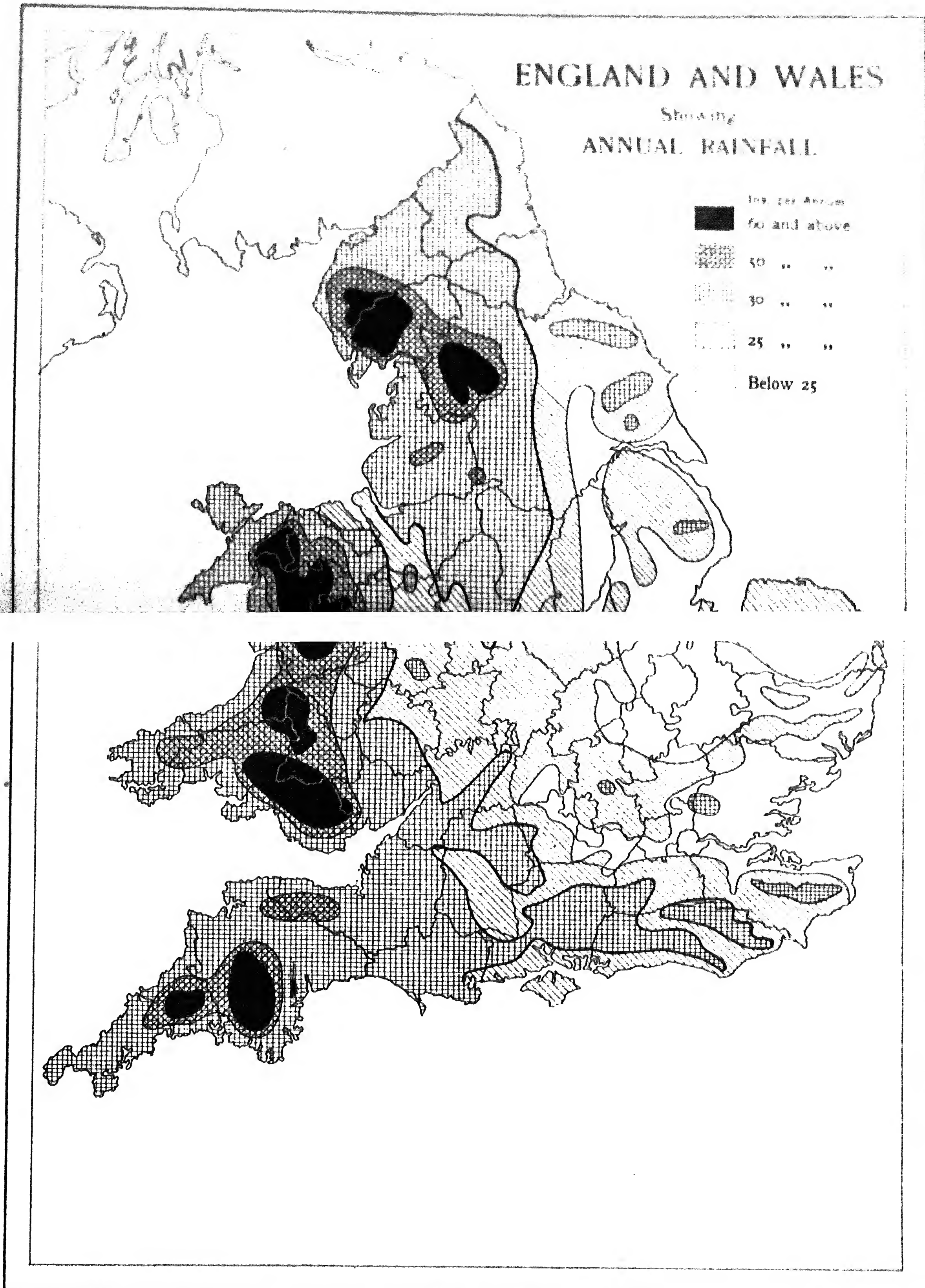
while the low rent and poor farming are associated with land that is poor.

An educational campaign may do something to lessen the differences revealed in the table, but we must not expect too much from it; there is a real



Increases in Areas under Corn and Potatoes, 1917 and 1918, England and Wales. The figures in the columns (+35 %, &c.) show the extent of the increase since 1916

difference in the conditions under which the best and the average men work, which can only be bridged—if at all—by careful scientific investigations, directed first and foremost to the discovery of the factors concerned, and, secondly, to the enquiry whether it is possible to control them in any way.


ENGLAND AND WALES
Showing
ANNUAL RAINFALL
Ins. per Annum
60 and above
50 " "
30 " "
25 " "
Below 25

Thus the problem of increasing crop production involves at least three types of factors: administrative—rearrangements of the cropping to make more economical use of the ground; educational—efforts to raise the standard of the average farmer, and to do something to bridge the gap between the average and the best; and, finally, scientific—investigations to discover the factors governing the growth of the crops, and so, perhaps, knowing them, to control them.

I propose to deal only with this latter problem, but I must say, at the outset, that we do not know a great deal about the factors concerned.

It is a fundamental principle in crop production that the environment must suit the crop. A study of the climatic map of Great Britain shows sharp differences in temperature and rainfall, the eastern counties being, on the whole, dry and cool, and the western counties moist and warm. On the whole, the eastern regions are thus naturally favourable for grain production, and the western for grass production. The agricultural experts of olden times hoped to control the weather, or, at least, to control the clouds and the hail. Mediæval writers on agriculture, following Palladius and other late Latin writers, give details of methods for doing this,[1] but we who are sadder and wiser leave rainfall and temperature to look after

[1] See Palladius, *Opus Agriculturæ*, Lib. I, XXXV. "Contra nebulas", "contra grandinem", &c., and later, in the same section, "Grandini creditur obviare", &c. The suggestions are to burn chaff and rubbish, to throw a russet garment on the millstone, to threaten the heavens with bloody axes, to have white vines round the garden, to fix up an owl with outstretched wings, to smear the tools with bear's grease; but the remedy must be applied in secret, and no one must see it done. Or, again, to carry the skin of a crocodile, a hyena, a seal, round the estate and hang it up at the gate, to carry a marsh tortoise about in the right hand, taking care to keep it back downwards, then, retracing your steps and still keeping it on its back, &c., with other details more picturesque than helpful.

themselves, and make no effort to control them; instead, we grow crops that suit the climate. Thus the crop map of the country corresponds fairly closely with the climate map, e.g. grass tends to be grown in the wet west and north-west, and wheat and other grain crops in the drier eastern and southern counties. The climate largely determines the distribution of crops.

But climate does not altogether settle crop production. The map showing yield of wheat is very different from that showing distribution. The highest yields of wheat are obtained in Lancashire, Northumberland, Anglesey, and Kent. In many of these cases the wheat is rather a special crop grown under some special conditions or by some special farmers, and there is some particular reason why it should be better than usual.

But our common crops are not single, homogeneous individuals: they comprise a large number of varieties, which differ considerably in their environmental requirements. Barley furnishes very good examples: the Archer types, with a stiffer straw and longer growing period, are later ripeners, and therefore better suited to cold, wet conditions than the Chevalliers, which ripen earlier, and therefore do better in warm conditions and light soil,[1] while on rich soils the Goldthorpe varieties flourish best. The Potato variety of oat, one of the most popular in Scotland, does badly in the south and east of England; Black Tartarian oats do well in the southern counties on the chalk land, and Goldfinder in the western counties. Yielder and Record oats do well on rich soils in moist climates, and Black Tartarian and Sandy

[1] See an interesting paper on this subject by Mr. E. S. Beaven, *J. Farmers' Club*, December, 1905. It should be pointed out, however, that the Archer types do well in the warm, dry Eastern counties.

on poor ones. Much information of this sort is current among farmers, but it needs collecting and sifting. Among the wheats, Rivett's is eminently suitable to heavy land, though it must be sown early, and Little Joss appears to prefer light land.

One of the great problems for the present is to make a careful study of the environmental requirements of the well-defined types of varieties, and one of the great hopes for the future is that new varieties may be found better suited to the various local conditions than those at present in common cultivation.

Although there seems no hope of controlling climatic factors, it is possible somewhat to mitigate their effects by modifying the environment. There are four general ways in which this can be done. The first process that must be carried out before anything else can succeed is drainage, to remove the excess of water and to make the soil drier and therefore warmer. In the main drainage problems are engineering, and lie outside our province. The old plan that worked exceedingly well in the 'sixties—the days of cheap farm labour—consisted in taking levels very carefully, then digging trenches of such depth that a proper outflow could be obtained, and, finally, laying porous drain-pipes in the trenches to carry away the water. This is still the most effective method, but it is costly, and is being replaced by another and cheaper method, known as mole drainage, in which a steel shell-like implement is pushed through the soil so as to make a tunnel 2½ inches wide. Contrary to what might be expected, the tunnel does not fall in, but persists for ten to fifteen years or more.

After this comes liming or chalking, one of the oldest of agricultural processes, and even now only in part understood. Liming has an obvious effect in neutralizing acidity, in improving texture and floc-

culating clay. It facilitates cultivation operations for all crops, and increases yields of some but not all—barley, for instance, responds, while potatoes and oats generally do not.

When this is done, cultivation proper can begin: this constitutes "the daily round, the common task", of the husbandman's life. It has been practised for ages, and has reached a high pitch of perfection by purely empirical means.

The skilful cultivator can reduce a sticky soil to a nice crumbly condition for sowing, he can break down clods to granules of the proper size, he can increase or decrease the water-supply and the air-supply to the roots of the plant, and appreciably modify the soil temperature. The methods adopted were at the beginning of the war under investigation in our laboratory by Mr. B. A. Keen. It cannot be said that we know much about the principles underlying them, or that they themselves have greatly improved during the last fifty years; they have, however, become cheaper. In spite of shortage of skilled labour, cultivation before the war on well-managed farms was still just as good as ever. The work was done by machine rather than by hand, but the machine was being steadily improved so that it should work as well as the hand.

Having improved the environment by these three methods, the fourth means of increasing the growth of crops is to increase the amount of plant nutrients in the soil. The old method of procedure was to add farmyard manure, and this still remains the most popular. The advance of agricultural chemistry has shown that the nutrient materials can also be added as inorganic salts, and great quantities of these are used every year. The salts are of three kinds, supplying respectively nitrogen, phosphoric acid, and

potash. Chemistry has also shown how to use them to the best advantage, so that crop growth is now possible with only a few hundredweights per acre of salts that would otherwise necessitate ten or more tons of farmyard manure.

Manures and fertilizers not only act as nutrients, but also as means of modifying the environment. Thus organic matter considerably alters the texture of the soil and its power of holding water, so that a plot treated with farmyard manure tends to be moister than an untreated one. Phosphates not only serve for the nourishment of the plant, but they also facilitate root development: they are therefore particularly useful in conditions where roots naturally cannot grow well, e.g. on heavy clay soils. Further, they facilitate the early stages of plant growth and hasten maturation, thus adding to their value on heavy land. Potassium salts tend to lengthen the life of the plant, and are therefore useful on light sandy soils where growth tends to finish early. These effects are not very great so far as yield goes, but they make a considerable difference to the certainty of a harvest and to the ease and cost of growing the crop.

Perhaps the main direction in which improvement is possible is the poor grass-land, and this because, when it was formed, it was usually considered too poor to be arable land. Over large areas of boulder-clay basic slag effects a remarkable improvement, especially when wild white clover seed is sown as well. Undoubtedly we could greatly increase the produce of our grass-land by this method, and it is being done. It thus becomes possible to maintain our present head of stock on a smaller area of grass and to liberate extra grass for ploughing up.

The British farmer quite understands these points, and he uses a great deal of the various fertilizers: no

less than 37 million tons of farmyard manure and well over a million tons of artificial fertilizers. Prior to the war the total amounts used each year were:—

	Estimated pre-War Consumption in United Kingdom.	Estimated Annual Value. Pre-War Prices.
	Tons per Annum.	
Farmyard manure ...	37,000,000	£11,000,000
Nitrate of soda	80,000	920,000
Sulphate of ammonia ...	60,000	750,000
Cyanamide (nitrolim) and nitrate of lime ...	10,000	110,000
Superphosphate	600,000	1,650,000
Basic slag	280,000	560,000
Guano	say[1] 25,000	250,000
Bones	" 40,000	200,000
Others	" 10,000	100,000
Total	1,105,000	£4,540,000

When these amounts of artificial fertilizers are divided out per acre of cultivated land, they are seen to be less than is given in Belgium, Luxemburg, or Germany, where the figures are:—

AMOUNTS OF FERTILIZER USED, IN HUNDRED-WEIGHTS PER ACRE, PRE-WAR CONDITIONS

	Belgium.	Luxemburg.	Germany.	Great Britain.
Phosphatic	1.10	1.36	0.66	0.6
Potassic	0.16	0.21	0.48	0.07
Nitrogen	0.48	0.07	0.18	0.10
Total artificial fertilizer ...	2.18	1.64	1.34	0.77[2]

[1] No good estimate can be made of the amount of guano, bones, and other materials used as fertilizers.

[2] 0.7–0.9, according to the estimate of the International Institute, Rome.

The potassic fertilizer is reckoned as containing 25 per cent K_2O. An estimate for British and German consumption, closely agreeing with the above,

It is customary to argue from these figures that the British farmer is greatly behind the Continental farmer in the use of artificial fertilizers. The force of the indictment is somewhat discounted by two important considerations:—

1. In Germany a considerable area of the cultivated land is light and sandy, and therefore specially needs potash, while in England great areas are heavy or loamy soils, which do not respond to potash except for special crops.

2. Germany grows great quantities of sugar-beet, which specially needs potash, while we do not grow this crop.

Further, the table omits altogether the enormous amount of feeding-cakes and meals imported from abroad and fed in the cattle-yards and sheep-folds of Great Britain, quantities which, in proportion to our acreage, are far in excess of those imported into Germany before the war. All these go to enrich our farmyard manure, and therefore our land.

The management of this manure leaves much to be desired, and a great deal of the combined nitrogen is at present dissipated; but the subject is being investigated, and there is reason to hope that considerable improvements may be obtained.

I do not suggest that we have yet reached a limit to the amount of fertilizers we can use. Many of our backward farmers can do more than they have done, and some of our poor grass-land and waste land can come into cultivation. I do not think, however, that the best farmers could well use much more artificials than they do at present. The following estimates of

is given in T. H. Middleton's *German Agriculture* (Cd. 8305), p. 36, where the phosphatic and nitrogen fertilizers are calculated as 30 per cent superphosphate and sulphate of ammonia, respectively.

possible fertilizer consumption have been made:—

	Pre-War.	Sir T. H. Middleton.	Sir Chas. Fielding.	E. J. Russell.
	Tons per Annum.	Tons per Annum.	Tons per Annum.	Tons per Annum.
Nitrogenous (expressed as sulphate of ammonia)	150,000		360,000	470,000
Superphosphate ...	743,000	1,367,000	1,643,000	1,730,000
Basic slag	263,000	892,000	1,463,000	

The broad result of the application of these four methods during the past fifty years has been to raise the efficiency of the production processes rather than to increase the yield. Prices of produce were low until recently and wages were rising; without these improvements corn production would have been impossible in this country. Thus, in the 'sixties—the golden days of farming for the farmer—wages were only 8*s*. to 15*s*. per week, and the price of wheat was round about 55*s*. per quarter. Just before the war the price was only 32*s*. per quarter, and wages had risen from 17*s*. to 25*s*. per week. The cost of production had therefore to be considerably diminished. Yet the average produce per acre was kept up—indeed it was somewhat increased.

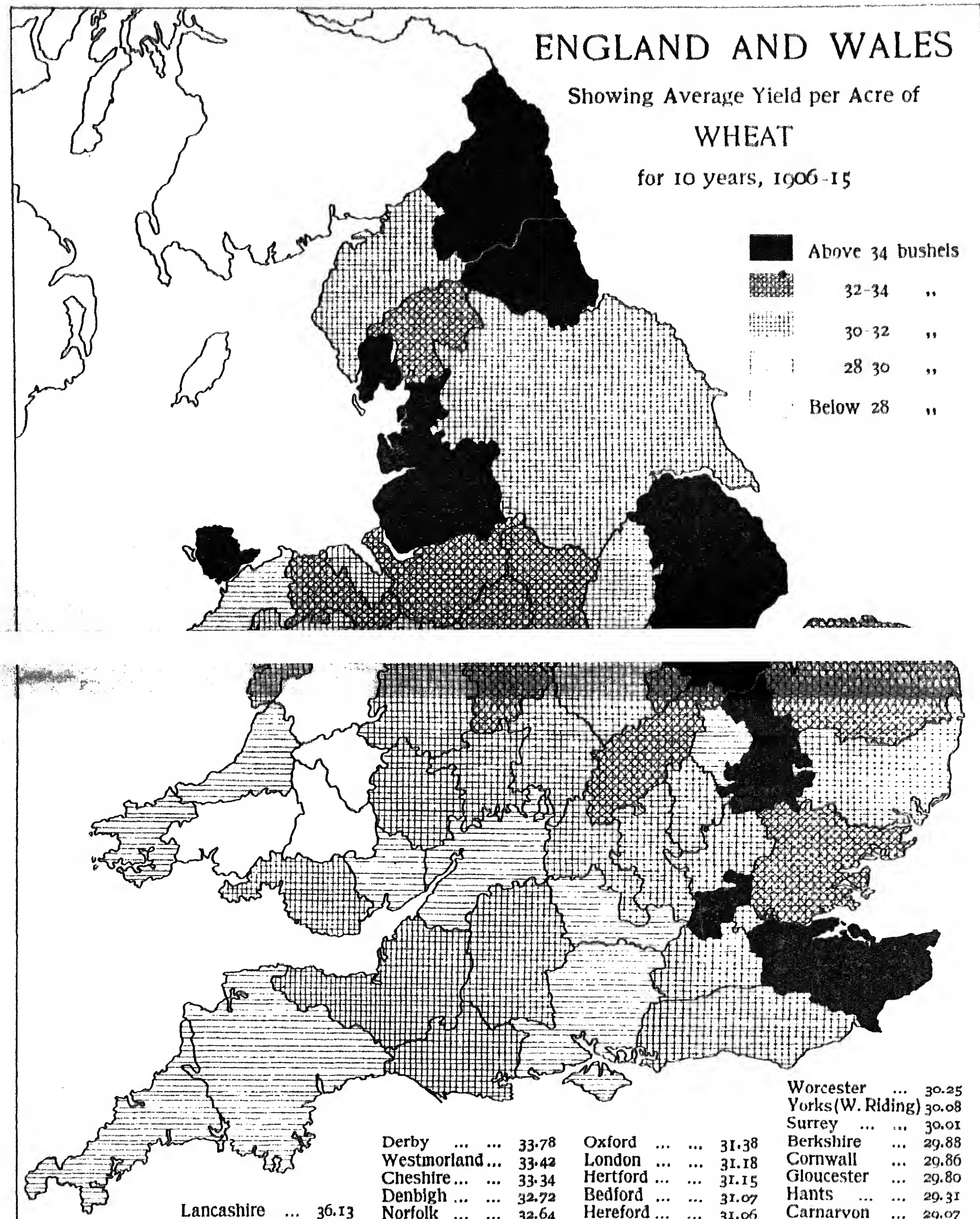
Strictly comparable statistics for the yield of wheat are only obtainable since 1885; they are plotted in the diagram opposite. The curve fluctuates a great deal, and its peaks are no better than they were in the 'eighties, nor apparently than they were in the 'sixties: we do no better in the good years than our forefathers did. But for the last fifteen years the crops have never fallen as low as they used periodically to go: we do better in the bad years. I am inclined to think that there is a real improvement:

ENGLAND AND WALES

Showing Average Yield per Acre of

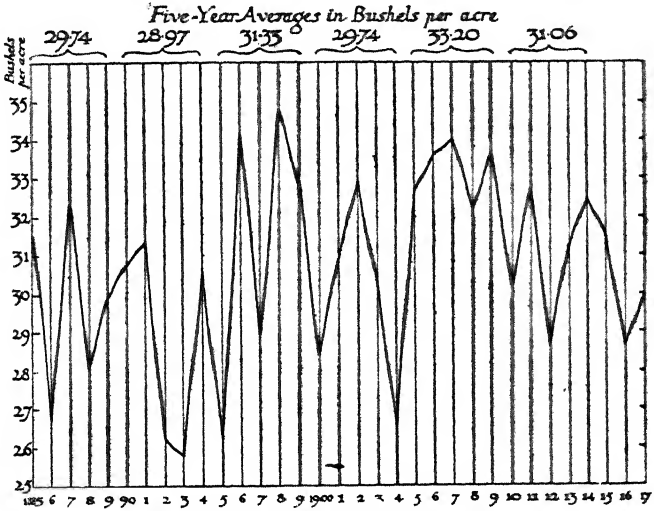
WHEAT

for 10 years, 1906-15



Lancashire ...	36.13
Northumberland	35.98
Kent	35.47
Middlesex ...	34.86
Lincoln	34.71
Anglesey ...	34.50
Cambridge ...	34.47
Durham	34.34
Northampton ...	33.92
Rutland	33.81
Derby	33.78
Westmorland ...	33.42
Cheshire	33.34
Denbigh	32.72
Norfolk	32.64
Stafford	32.30
Essex	32.10
Sussex	31.91
Wilts	31.76
Suffolk	31.75
Leicester ...	31.53
Somerset	31.49
Yorks (N. Riding)	31.40
Dorset	31.39
Oxford	31.38
London	31.18
Hertford	31.15
Bedford	31.07
Hereford	31.06
Yorks (E. Riding)	31.04
Buckingham ...	30.93
Salop	30.87
Merioneth ...	30.85
Glamorgan ...	30.85
Cumberland ...	30.74
Warwick	30.49
Flint	30.48
Notts	30.37
Worcester ...	30.25
Yorks (W. Riding)	30.08
Surrey	30.01
Berkshire ...	29.88
Cornwall ...	29.86
Gloucester ...	29.80
Hants	29.31
Carnarvon ...	29.07
Pembroke ...	29.02
Hunts	28.95
Devon	28.47
Cardigan ...	28.44
Monmouth ...	28.28
Brecknock ...	26.21
Montgomery ...	25.20
Radnor	24.85
Carmarthen ...	23.78

when a crop is looking bad scientific advice is more likely to be taken than when it is looking well. And, moreover, the new varieties tend to excel the old ones in a bad season even more than they do in a good one. Thus by levelling up the bad years we may hope to achieve a distinct gain in crop produc-



Wheat grown in England. Yield per acre in bushels each year for the past 33 years

tion. It is in this direction, I think, that lie our best hopes for increased crop production.

Turning now to the good years, we seem to have got into an *impasse*, and, in spite of all our experiments, we have not improved on our average wheat yield of about 34 bushels. Germany has made greater advances than we have during the past thirty years, but only because she began at a lower level; she has not exceeded this yield.

But I am not at all pessimistic about the future. It is possible to define the factors which at present limit our yields and keep them down. If it appears that they can be controlled, we can to that extent push our yields up even in the best years.

One of these limiting factors is strength of stem. When a wheat crop is manured it increases in amount, but the stem does not become proportionately stronger. After a time the head and leaf become too heavy for the stem, and the crop sooner or later falls down; in the farmer's language it is "laid" or "lodged". Laid corn is very difficult to harvest, and it is apt to be spoiled before it can be got in. It represents the limit beyond which the farmer cannot go in manuring his crops. The 32-bushel average for the wheat crop, which we have long attained, and which no country much exceeds, is mainly determined in this country by the fact that most farmers fear to go higher because of the danger of "lodging". Excellent examples of "lodged" crops can be seen in the Fen country almost every year.

In the case of barley, the phenomena have been well described by Mr. Beaven.[1] "When barley goes down just as the grain is ripening off, the whole plant often leans from the crown of the roots, which is generally about half an inch under the surface. This can hardly happen without the roots being to some extent loosened, and therefore probably depends on the condition of the soil or the strength of the roots. Whether or not the Archer type of barley is the more strongly rooted, it will be generally agreed that the Archer barley does not go down at this stage as easily as the Chevallier." Besides this general fall, barley seems to be specially weak in the top node or knot in the stem: it is not uncommon to see whole

[1] *J. Farmers' Club*, December, 1905.

fields bent or kinked at this point. The Goldthorpe variety tends to kink right up in the neck, near the head, and thus suffers considerable loss through breaking off at the head.

The problem of strength of the straw is one of the most important before us to-day. It is not wholly a matter of manuring. Nitrogenous manures tend to increase lodging, but this does not necessarily mean that they weaken the stem; in point of fact, they increase the size of the head and of the leaf, i.e. the weight the stem has to carry. Lack of potash, on the other hand, undoubtedly weakens the stem. Some soil factor appears to be concerned, for stems are much more rigid on some soils than on others. So far no very definite anatomical difference has been observed between the strong and the weak stems. The length of the internodes has something to do with it, long internodes on the whole tending to weaken the straw. Possibly also a physiological factor such as turgor is concerned. Until we can increase the strength of our cereal stems I see very little chance of greatly increasing our yields.

A further important problem requiring investigation is the formation of grain. There is some factor, soil or climatic, or both, that determines whether a plant shall make much or little grain. On the brick earths of Sussex and East Kent wheat and oats form great quantities of large grain; the straw is stiff, and carries heads well set with large, plump grains of corn. On the other hand, the sands of Sussex and the clays of the Home Counties, however highly manured, do not give anything like the number of grains per plant. Again, in the Fens, corn grown in districts east and north of the Little Ouse, on the so-called sandy fen, does not produce as much grain per plant as corn grown west of the river on the clay

fen. No fertilizer overcomes this difficulty. Occasionally, in specially favourable seasons, the proper conditions are realized on some of these unsuitable soils: at Rothamsted we had such years for wheat in 1863 and 1864, when our crops rose to 56 bushels per acre; and for barley in 1854, 1857, 1861, and 1913, when the yield went to 60 bushels per acre.

Another phenomenon that may be closely related is tillering. When the wheat plant germinates it sends up a single shoot. After a time, however, a number of new shoots spring from the base of this shoot, so that there may be ten or a dozen stems from a single seed. This is spoken of as tillering or stooling. Tillering is not wholly, perhaps not even mainly, a question of nutrition, though that is a factor. The unmanured plot on Broadbalk field has received no manure of any sort since 1839; the plants tiller, but the shoots remain undeveloped, only one or two stems carrying any decent-sized heads. On the adjoining plot, receiving farmyard manure, the tillering is better, and the side shoots all develop. Tillering is improved by constant cultivation: some remarkable wheat plants can be obtained by working under garden conditions. A well-known Eastern method of growing wheat, which is also practised in Russia, consists in periodical hoeing and earthing up of the plants; a great increase in tillering is thus obtained.

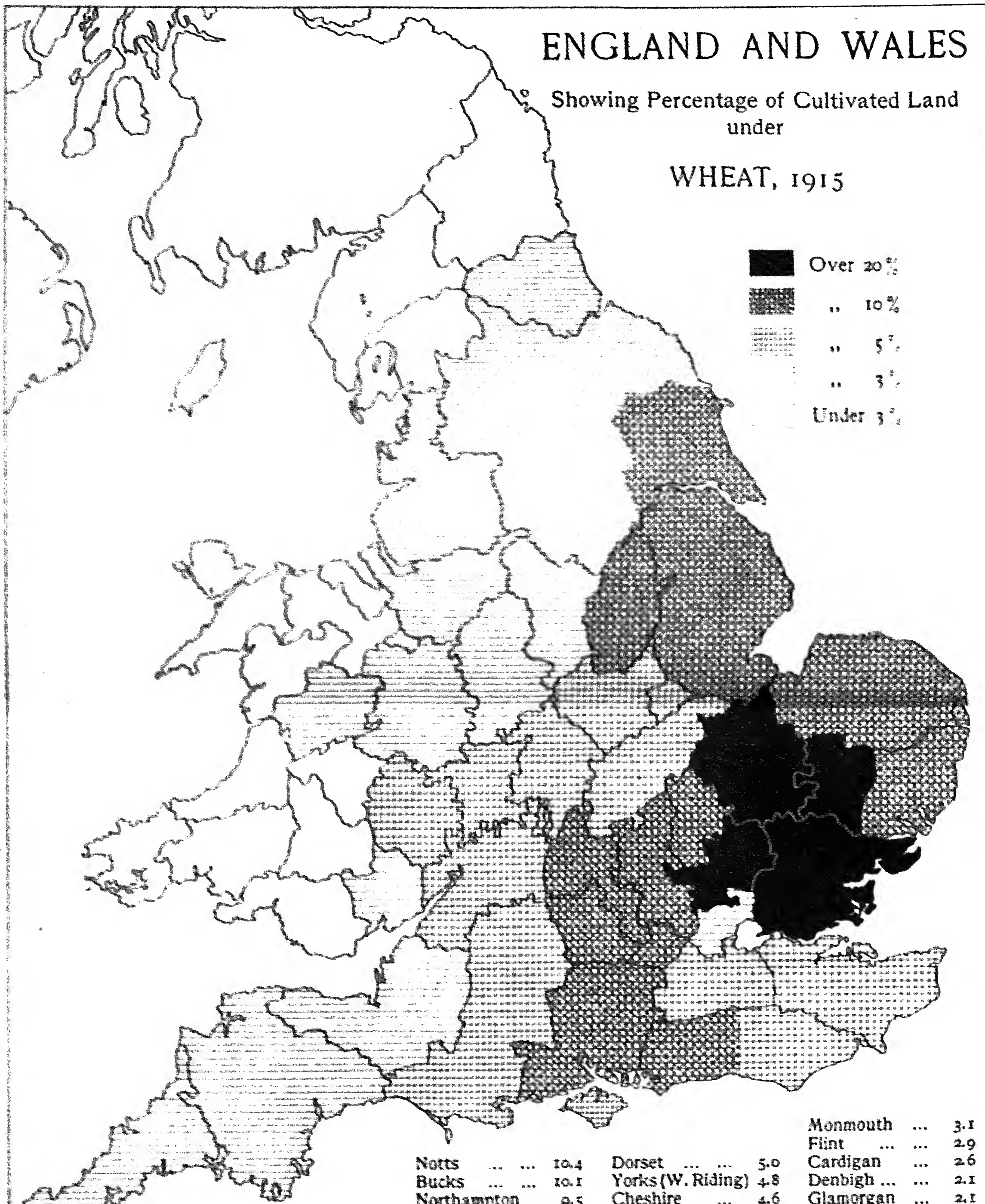
The principle was tested in the eighteenth century by Jethro Tull with remarkable results. During the last few years it has been further developed by Demtchinsky,[1] whose method was tested both in France and Germany; the yield per plant was greatly increased, but, unfortunately, not the yield per unit

[1] See N. and B. Demtchinsky, *Méthode pour obtenir de Forts Rendements en Céréales*, Paris, 1913; and also A. Einecke, *Landw. Jahrb.*, 1911, **41**, 281–335, where the method is criticized.

ENGLAND AND WALES

Showing Percentage of Cultivated Land under

WHEAT, 1915



County	%	County	%	County	%	County	%	County	%
I. of Ely	25.7	Suffolk (E.) ...	17.5	Notts	10.4	Dorset	5.0	Monmouth ...	3.1
Cambridge ...	22.6	Lincoln (Kesteven	14.6	Bucks	10.1	Yorks (W. Riding)	4.8	Flint	2.9
Huntingdon ...	20.9	Norfolk	13.6	Northampton	9.5	Cheshire ...	4.6	Cardigan ...	2.6
Herts	20.7	Lincoln (Lindsey)	12.9	Gloucester ...	9.1	Devon	4.6	Denbigh	2.1
Essex	20.5	Berks	12.7	Worcester ...	8.7	Salop	4.6	Glamorgan ...	2.1
Suffolk (W.) ...	20.0	Sussex (W.) ...	12.5	Wilts	8.6	Somerset ...	4.5	Carmarthen ...	1.8
Lincoln (Holland)	19.8	Oxford	12.1	Warwick ...	8.3	Staffs	4.5	Radnor	1.6
Bedford	18.9	Hants	11.1	Kent	8.3	Lancs	4.3	Brecknock ...	1.5
		Yorks (E. Riding)	11.1	I. of Wight ...	8.1	Derby	3.9	Pembs	1.2
				Surrey	8.1	Yorks (N. Riding)	3.8	Northumberland	1.0
				Sussex (E.) ...	6.7	Cornwall ...	3.8	London	0.9
				Rutland	6.7	Middlesex ...	3.6	Merioneth ...	0.5
				Hereford	6.1	Durham	3.3	Anglesey ...	0.4
				Leicester ...	5.7	Montgomery ...	3.2	Carnarvon ...	0.4
								Cumberland ...	0.3
								Westmorland	0.1

Figures from "Agricultural Statistics". Acreage and Live Stock Returns. Vol. L, pt. 1, 1915.

area. The same principle has been applied by Mr. Seeley[1] in our own country. The results are tantalizingly sufficient to show that there is something in the principle if only we could find the right application.

Tillering is also stimulated, as perhaps might be expected, by mechanical injury to the plant, such as rolling with a heavy roller or sending sheep over the land in spring to eat some of the young shoots. Unfortunately we know very little about the process of tillering, and cannot therefore suggest other or better ways of controlling it.

Turning now to root crops—swedes, turnips, and mangolds—the swelling of the root is of considerable importance, because unless the root goes on swelling the translocation of sugar from the leaf apparently does not continue long; small roots contain more dry matter than large ones, but not a great deal more. Swelling is promoted to an extraordinary degree by dressings of phosphates; indeed, the chief use of phosphate hitherto has been for this purpose. On the Agdell field the swedes grown without phosphates are no larger than radishes, yet the same plot will carry quite good crops of barley and wheat. As soon as phosphates are added the swedes swell up to their normal size, and produce the usual amount of sugar per acre. We know of nothing else that produces the same effect. The formation of tubers on the potato plant may be a related phenomenon, and is of equal or greater importance. Phosphates cause more tubers to form, and also—perhaps therefore—increase the amount of starch stored up.

There are two broad methods of attacking these problems. One is to find by search varieties of crops possessing the desired properties to a marked degree,

[1] *Journ. Farmers' Club*, May, 1915.

e.g. to find wheats capable of tillering, of standing up, or of "corning out", i.e. yielding a high proportion of good plump grain, and then to breed these qualities into varieties lacking them but possessing other desired qualities.

The other method is to try to discover the significance of the property itself: the cause of the strength of the straw, the meaning of corning out and of tillering, and then to go a step further, and try to control it. The first method achieves results, but the second is the more satisfying, and, in the end, the more certain.

Finally, there is an important aspect which has not yet received the attention it deserves. Crops must be produced without the competition of weeds and free from the depredations of fungi, insect pests, bacteria, and other organisms that attack them. The mortality among plants is probably at least as great as the mortality among animals or children, and yet we make very little attempt to deal with it. Plant pathology is almost a new subject.

One of the most important crops for the plant pathologist to investigate is clover. This crop might be made the basis of our farming; it grows extremely well, produces one, and in the case of some varieties two, good crops a year of most excellent animal food, and when ploughed in adds to the soil great stores of nitrogenous organic matter built up with the co-operation of nitrogen-fixing organisms growing in the nodules of its roots. Excellent crops of wheat can be obtained after a good crop of clover.

But unfortunately the crop is peculiarly liable to disease. In some cases it cannot be grown oftener than once in six or eight years, or occasionally even longer. Two pests are known—an eel worm (*Tylenchus devastatrix*) and a fungus (*Sclerotinia*). As to possible treatment, however, nothing is known.

The only advice one can give is to abstain from growing the crop oftener than once in eight years or so, but this is unsatisfactory, because one would like to grow it every third or fourth year. Some varieties suffer less than others, e.g. Alsike less than Red Clover.

Another important disease is finger-and-toe, an organism that enters turnip or swede roots and causes malformation, and very soon decay. Fortunately this cannot tolerate a neutral or alkaline medium. It is possible that the hydrogen ion concentration of the soil solution may furnish a valuable indication as to whether particular pests are or are not to be expected. An interesting investigation was made in North Maine,[1] U.S.A., of two soil types, both extensively cropped with potatoes: on one—the Washburn loam—potato scab is common; on the other—the Caribou loam—the scab is rare. In the latter case the exponent is 5.2, in the former it is 5.9; the more intense acidity of the Caribou loam apparently being beyond the limits of tolerance of the organism.

But disease organisms are only part of the trouble. One of the most efficient ways of building up soil fertility is to leave the land in grass for a period of years. Considerable quantities of plant residues are added to the soil, and nitrogen-fixing organisms, both free-living and symbiotic, carry on their wonderful work of taking up gaseous nitrogen from the air and synthesizing it into protein. Of all bacterial processes this is perhaps the most fascinating and the least understood; it well deserves the attention of a vigorous biochemist who is looking for a big problem.

The practical importance of the process is extraordinarily great. It is in this way that much of the fertility of our soils was built up, and it is this store

[1] L. J. Gillespie and L. A. Hurst. *Soil Sci.*, 1917, 4, 313.

of accumulated fertility on our grass-land that is standing us in such good stead in our day of trouble. Lincolnshire potato growers in days of peace were willing to pay £15 per acre for the privilege of breaking up grass-land. In the north of England and in Scotland it has been customary to leave the arable land for a period of years in grass, with a view to building up this reserve of fertility. In the south of England the grass is only left for one year, but another method is locally adopted which achieves the same purpose; crops are grown for the express purpose of ploughing them in or allowing them to be eaten on the land. This practice might with advantage be much more widely used. One great difficulty is to find suitable crops that will germinate and grow in the rather dry soil conditions usually prevailing after the main crop has been gathered. This problem I hope our breeders will be able to solve. But there is another and more formidable difficulty. When vegetable matter is added to the soil there is not only a great increase in the organisms decomposing organic matter and liberating from it the elements of fertility—which we may regard as beneficial inhabitants of the soil—but there is a marked increase in certain pests, such as leather jackets, wireworms, &c. The benefit we hope to derive from the liquidation of our capital in ploughing up grass-land in our present emergency is seriously threatened by the depredations of these pests, not only in the first year but in the second and third. No cultivation method can be relied upon to repress them entirely; the only reliable treatment is to find some efficient soil insecticide. This problem is being seriously attacked in the Rothamsted Laboratory: it is very similar to another which has caused us a great deal of trouble and has never yet been solved—the

search for an efficient soil antiseptic. For some time it has been known that partial sterilization increased the productiveness of the soil. For nursery work cresylic acid has turned out, on the whole, a suitable agent, but it has disadvantages. What we want is some effective method of treating the soil so as to kill all organisms, excepting, only, the resistant spores of the useful bacteria. Perhaps after the war some of our present poison gases may be found to solve the difficulty for us; if we could use them for purposes of peace we might truly be said to have beaten our swords into ploughshares.

E. J. R.

GRASS-LAND AND ARABLE

It is a remarkable fact that the farmer and the scientist alike have in the past been prone to regard grass and arable farming as two entirely separate branches of the industry; so much so had this become the case that when the war broke out we were faced with the difficult position that an appreciable proportion of our farmers were flock-masters pure and simple —mere dog-and-stick men—men who had long since lost the aptitude of walking behind the plough, and with little or no experience of the fascinating mysteries of tillage. Other farms were run on a chess-board plan, the rules set out at great length in antiquated leases, laying down suitable forfeits to be paid by such as moved the plough over the green or grass-land squares. The great advances in agricultural science during the last decade in this country have, moreover, been connected chiefly with arable crops and the improvement of existing grass-land, but little new work appearing on prepared or artificial grass since the important papers of De Laune, Fream, and Carruthers.

There were, however, practical agriculturists who were beginning to realize that our chess-board system of farming was about played out—pre-eminent amongst these was the late Mr. Elliot, who, in his *Clifton Park System of Farming*, wrote convincingly on the basis of his actual experiments, advocating far greater resort to the temporary ley, and the taking of the plough

over the whole farm.[1] That insufficient attention has been paid to the teaching of Mr. Elliot is I fear shown by the fact that the *Clifton Park System of Farming* was for a long time, and I believe still is, out of print.

The relation that exists between grass-land and arable had also before the war been appreciated at some of our Agricultural Colleges, but very little exact experimental work has been conducted in connection with the problems involved. Most of the grass-land work has been on the Cockle Park lines, and has concerned itself with the improvement of existing pastures.

Professor Gilchrist and Mr. Walker in the North of England, Mr. Porter in Herefordshire, and the Agricultural Departments of the Welsh Universities have, however, done much to establish the value of Wild White Clover, to encourage the use of the temporary ley, and to demonstrate the interdependence of good grass-land and good arable farming, whilst Professor Somerville had demonstrated by a series of pot experiments the influence of White Clover residues on subsequent arable crops.

A few advanced farmers had, moreover, before the war, returned to tillage on an extensive scale—Mr. Falconer and Major Spence may be mentioned in this connection, both having read important papers on their methods at the Farmers' Club. In the main, however, both scientific and agricultural opinion was quite unprepared for a return to tillage on a grand scale.

It has, of course, to be realized that extensive areas in the British Isles are not suited for corn-growing, at least for human consumption, or it is at best a very hazardous undertaking, and that these regions of high

[1] That is to say, by putting fields down to grass with carefully selected seeds mixtures, and again ploughing the turf after it has been in grass about four years.

rainfall are in the main capable of producing good and remunerative grass. It has not been sufficiently appreciated, however, that grass production and crop production are not incompatible, or that under certain conditions artificial or prepared grass may be far more productive than permanent or so-called permanent grass.

Much as may be said for the merits of cattle and milk production on purely arable lines, it will always be most economical, if not absolutely essential, to depend largely on grass in districts of high rainfall. This brings me to a discussion of the theory of the temporary ley, and to a detailed consideration of some of the problems to be solved if the temporary ley is really to come into its own, and to replace, as I think it ultimately will, even our famous fattening pastures, the land devoted to which should yield both bountiful arable crops and productive temporary leys. By a temporary ley I mean a field that is seeded down to grass artificially and so left for about four years, and then re-broken and put through a course of tillage again. This is, of course, a procedure often adopted on certain fields, but not usually as a part of a well-considered working plan on which the whole economy of the farm is based. A temporary ley has failed in its purpose unless, firstly, it has established itself rapidly; secondly, it has been uniformly productive throughout the whole of its short life; thirdly, that when it comes to be broken the residues considerably add to the fertility of the field for the benefit of subsequent corn and root crops; fourthly, that it makes a clean and weedless arable field; and, fifthly, that the aggregate produce from the field whilst in grass is as great or greater than would have been the "keep" from the same field had it been left under permanent grass.

It will now be my business to enquire how a temporary ley is to be made to achieve its five essential functions, and why in practice it so seldom does.

To deal firstly with what is perhaps the most important duty of our temporary ley, namely, to build up fertility. This turns upon having a turf full of clover to plough down at the end stage of the ley, and this depends upon proper manurial treatment and stocking, and upon sowing the right clovers in the first instance. The degree of persistence of the clovers under varying conditions is therefore at once seen to be a matter of prime importance to agriculturists, but as far as I know it has not been made the subject of detailed research. The clovers are most variable in this respect. Of the Red Clovers it may, in general, be said that those of the late-flowering type, that is to say, those with rather a deep-going tap-root, and that flower only once in a season, persist longer than those of the broad-leaved type, and there is little doubt that, for use in Britain, Red Clover seed harvested in Britain gives plants of more prolonged duration than seed from oversea sources—seed from Brittany is generally considered to give more durable plants than other foreign seed. Small-scale trials I have myself conducted in Wales have tended to confirm this view, and incline me to go even further, for I found that on poor fields in Mid Wales at comparatively high elevations the Red Clovers which persisted best were those (intrinsically poor samples so far as germination was concerned) which had been harvested on thin soils at high elevations and under adverse weather conditions in Montgomeryshire or on the Cotswolds, whilst Chilian Clover (the most attractive-looking seed on the market) almost invariably died out after the first year. Alsike Clover, moreover, in cold and wet

ricts often persists longer than Red Clover, and is I think a fact not sufficiently appreciated by ners. From the fertility point of view White ver is, of course, pre-eminent among clovers, and value of Wild White Clover as a rapid herbage-ner and fertility-conserver is now a proved fact. ite Clover is, moreover, the most permanent of herbage Leguminosæ, and a widely distributed igenous plant, which may be largely developed by quate manurial treatment.

rom what has been said as to clovers it will be arent that Wild White Clover should be an im-tant ingredient in all leys that are to be left down longer than two years, and that late-flowering Red ver and Alsike Clover should take a prominent ce in mixtures for leys of two to three years dura-. It is hardly necessary to add that phosphatic nures and lime are essential to a proper develop-nt of clovers, and that these ingredients either lied to fields immediately before or subsequent the formation of a ley, by assisting sward forma-, have an accumulative effect on the fertility of the d.

ley, I have said, should give rise to clean arable d when it is ploughed down. It will be well, refore, to enquire what weeds from a ley are likely oul the arable land and what weeds from an arable d are likely to foul a ley.

he following weeds in particular are equally harm-on prepared grass and on arable land:—

Creeping Thistle.
Docks.
Sheep Sorrel.
Bent.
Creeping Buttercup.
Creeping Wild Mint.

Of these Dock and Sheep Sorrel are frequently introduced with the clovers, and when so introduced adversely influence both grass and subsequent arable land. Creeping Thistle is occasionally brought in with the seeds, especially in Canadian and North American clovers, but seldom to a serious extent. The Creeping Thistle responds to manurial treatment, and it becomes very plentiful on pastures that are continually sheeped, and I more than suspect that basic slag encourages its development; thus land full of Creeping Thistle should be well cleaned before it is allowed to pass from arable to grass, or vice versa. A cleaning crop should, therefore, always be taken off a finished ley on being first ploughed up—the potato is perhaps the best crop for this purpose.

An arable field foul with the above weeds should not be put down to grass in a spring corn crop, as is usually done; it would be better to take an early or mid-season crop of potatoes and so thoroughly clean the land and then sow down the grass under a plant like rape if the potato crop can be removed in time, or under rye sown in August or early in September.

Bent, Creeping Buttercup, and Mint are perhaps the worst weeds that are passed on from arable to grass and from grass to arable. If a field has been well cleaned before it is sown down to grass, they are weeds which take time to establish themselves on a ley, and, indeed, if a good mixture has been used and the ley well cared for, they should not be much in evidence until subsequent to the fourth year. It is lack of appreciation on the part of farmers as to the relationship between grass and arable that is responsible for the trouble caused by Bent. The average farmer has not the courage to plough down a ley while it is full of clover—he deems such a sward to be too valuable from the herbage point of view; so

he waits till the herbage affords practically no keep—that is to say, till the clover has died out and the sward is little but Bent, and thus at once fouls his arable land and loses the fertility he should have assured for his subsequent crops.

I now come to what are scientifically perhaps the most interesting problems connected with the temporary ley, namely, how to establish a sward quickly, and how to make it uniformly productive over the whole of its existence. The pioneers on herbage questions concerned themselves to find out what species *qua* species had the greatest nutritive value, under what soil conditions these species *qua* species flourished, and at what season of the year these species *qua* species matured. All this they ascertained, and to the lasting benefit of agriculture. They proceeded to argue, however, that the selection of a seed mixture then became a mathematical problem pure and simple: you wanted so much ground covered with top grass, so much with bottom grass, such and such a proportion of early species, a proper proportion of mid-season and late-maturing species, and there was the basis of your seeds mixture; and, provided you knew the germination of your seed and the approximate number of seeds to the pound, a sliding scale would do the rest. But, unfortunately, there are other factors affecting the problem not yet capable of mathematical solution. What, for instance, is going to be the competitive interaction between the species you sow? How is it all going to be affected by those indigenous species which have a knack of springing up naturally? And, furthermore, what of the antecedents of the seed of the desired species you sow—where has the seed come from, and is it really going to succeed and fill up its allotted portion of ground?

If a mixture is to form a sward rapidly, it is essential that weeds should be crowded out from the beginning, and that the sown species establish themselves immediately; it is also essential, if a ley is to be uniformly productive over four years, that those species which are sown chiefly for the first two years do not hamper the development of those which will be relied upon during the last two years. Mr. Elliot appreciated this when he advocated very large sowings of Cocksfoot and decreased sowing of Rye-grass. The excessive sowings of Rye-grasses in common use are largely due to the fact that Rye-grass is known to contribute very largely to the best old pastures on really good soils; it does not follow, however, that they will do so on poorer soils, or that they will persist from commercial seed—the mathematical basis of drawing up a seeds mixture is hopelessly wrong in respect to Rye-grasses.

The Rye-grasses when sown to excess will, of course, ensure a heavy crop of hay, and the farmer is too apt to judge his ley almost entirely by his first hay crop. Cocksfoot and Timothy, however, if they are not set to compete with too much Rye-grass will, as my own trials in Wales have shown, yield almost equally good crops in the first year, and do much to ensure a remunerative herbage in subsequent years. So the first essential in the formation of a good ley is to decrease the normal Rye-grass sowing and add to the Cocksfoot and Timothy, in so far as an adequate supply of bulky top grasses is concerned. The second essential, which is often overlooked, is to establish rapidly a good "soul" or bottom sward, and to maintain this until the ley is ploughed down; in order to do this it is necessary to establish species which have in the past been generally considered as only necessary for permanent pastures. The most desirable of

these are Wild White Clover and Rough-stalked Meadow Grass, and there is little doubt that the Wild White Clover favours the development of Rough-stalked Meadow Grass, as is well exemplified by some of Mr. Porter's plots in Herefordshire. Wild White Clover can be established on almost every soil by adequate manurial treatment, and Rough-stalked Meadow Grass will succeed even on thin and poor soils to a greater extent than is generally supposed, provided the rainfall is adequate. The Wild White Clover and Rough-stalked Meadow Grass combination is most valuable from the point of view of smothering out weeds and for maintaining a close turf. I do not believe that Rough-stalked Meadow Grass is of great value as a herbage plant for animals, for, although of high nutritive value, it is not readily eaten by stock. A good ley should in short have all the advantages of an old permanent sward with the additional advantage that the one or two hay crops taken should be more bulky than that from an old meadow, contain far more Red Clover, and altogether less weeds. For it must be remembered that the heavy crops of hay obtained from "fine old meadows" often consist of one-third to one-half of plants like Soft Brome, Yorkshire Fog, Sorrel, and Hard Heads.

I have spoken of Rough-stalked Meadow Grass and Wild White Clover as plants required to give what I might call the permanent touch to a ley; whilst Rye-grass, Red and Alsike Clovers will add valuable bulk during the first two years, and Cocksfoot and Timothy during the whole period. It now remains to be asked if the list of plants desired should end with these. There is no doubt that, for reasons which will be explained later, it is desirable to add to the list. The permanent plants which suggest themselves are

Meadow Fescue, Meadow Foxtail, with some of the fine-leaved Fescues, Tall Fescue, and Crested Dog's-tail; but unfortunately all of these, with the exception of Crested Dog's-tail, are very difficult to establish. This brings us to the farmer's chief objection to the temporary ley. He says it takes from upwards of six years to establish a herbage equivalent to a permanent sward, and that even by sowing permanent grasses it is not possible materially to hasten matters; but it has also been assumed that the permanent grasses which eventually establish themselves owe their origin to having been included in the original seed mixture. This is, however, by no means always the case. Mr. Jenkin in North Wales and myself in Mid Wales have been able to show that most of the fine-leaved Fescues, and several other species met with in old leys, are almost entirely due to the indigenous plants which have established themselves naturally, quite independent of what seed may have been sown. Meadow Fescue, again, a seed which is very largely sown for four to eight years leys, never justified itself from commercial seed in many of our grass-land districts. It does so in a few localities on very fertile soils. Meadow Foxtail, a most valuable plant, very seldom, if ever, establishes itself from commercial seed to any extent, even on soils which have been regarded as eminently suitable to this plant. I have seen fields adjoining each other where the one, an old permanent meadow, was full of Meadow Foxtail, whilst the adjoining ley, over six years down, although this seed was included largely in the mixture, contained but little or no Foxtail herbage. I have, moreover, met cases where a ley in its first year was full of Rough-stalked Meadow Grass, although not an ounce of the seed had been sown. Cocksfoot, however, is a plant which will not establish itself at

all quickly unless the seed is included in the mixture in the first instance, although after a lapse of a number of years it will, if then introduced, even in the smallest amount, overrun fields that are continually used as meadows.

The foregoing facts should teach a very important lesson, namely, in drawing up a mixture it is important to make a close study of the older pastures of a district, in order to ascertain what are the valuable herbage plants that chiefly contribute to the sward. This will form a basis of plants that it is desirable to introduce, plants which may be regarded as being locally indigenous. As I have already pointed out, however, it by no means follows that sowing the commercial seed of these species will produce the desired results.

We have two facts to direct our further enquiries, namely, the proved success of Wild White Clover and that in many districts the seed of Chilian Red Clover produces tender plants of short duration.

It seems evident, therefore, that in the case of the vast majority of our herbage plants something more than the selection of species as such is desired, and that the place of origin of the seed is also important; but is this place of origin a simple factor or is it interwoven with the difficult question of sub-species and sub-varieties? That it is not a simple factor is suggested by a number of considerations—for instance, by the difference between Cocksfoot obtained from New Zealand and from Denmark. Professor Gilchrist has shown that New Zealand Cocksfoot produces a bigger and more bulky plant than the seed from Denmark, a plant therefore more suitable for temporary leys, and observations I have made in Staffordshire tend to confirm this. For my own part, I am driven to the conclusion that we shall

have to recognize something akin to "habit races the higher plants, for I think that, as our study grass-land becomes more thorough, we shall find t local indigenous varieties exist—varieties that d morphological separation—unless, indeed, a sys matic study of minute differences in internal m phology may reveal characters capable of recogniti It is evident, at all events, that certain species locally strongly indigenous, and that these variet are endowed with properties that make them far m successful colonizers each in its own special local than are the plants from seeds obtained from t ordinary commercial sources.

The foregoing considerations open up a wide an in this country, an almost totally unexplored field research, namely, the building up of persistent in genous and withal productive herbage plants. T problem is more involved than is that of selecting breeding arable-land plants, for in that case we a at most concerned with biennials, and but few cro are in agriculture treated as biennials. Adver climatic conditions can be got over to a large exte in the case of annuals, or functioning annuals, b producing rapidly-maturing strains which comple their life-circle during the period of most favourab conditions. Thus, when perfecting wheat, mangel or sugar beet, you may intensify the characters yo desire, and, without knowing it, carry along deficie cies which would make your new variety incapable surviving had it to reproduce or maintain itself und conditions of competition such as our four-year-pe sisting herbage plants most successfully contend with

It is probable, therefore, that the first step to b taken in building up improved strains of herbag plants is a detailed study of indigenous species fro an essentially local standpoint; the essence of th

problem being to graft on to a persistent stock capable of rapid colonization those all-important agricultural characters of nutritiousness and bulk. Before this can be done, and before we can employ Mendelian methods or adopt the more correct and accurate plans of selection, we must know a great deal more about our indigenous plants, and, if possible, be in a position to fasten on to definite characters to work from.

I have, in this connection, been much struck with the wealth of leguminous herbs always met with on heathy pastures near the sea; it is not only the Leguminosæ, however, that colonize these heaths, and which rapidly gain a footing on land put away to artificial grass—Crested Dog's-tail, Rough-stalked Meadow Grass, and a dwarf and persistent form of perennial Rye-grass are equally characteristic of such areas. It is a question then whether these plants are definite varieties (if only biologic), and if they would not form peculiarly good stocks upon which to build. It is most desirable to ascertain the trueness to type of these persistent plants. Seed should be collected from selected species from such heaths and the produce sown in widely different habitats and compared against the progeny of seed obtained from the local plants of the same species and against the ordinary commercial seed. From the point of view of breeding persistent plants, it will be necessary to decide whether, say, the maritime varieties may be used for general purposes or whether it will be found to be necessary to build upon the indigenous varieties for every characteristic district separately. I can see no solution to this problem other than by a very thorough and complete series of trials—trials that are long overdue in relation to the whole problem of acclimatization. It may well be that the conditions under which seed is harvested accentuate certain potentialities in a par-

ticular strain in the generation immediately following; thus Chilian clover seed tends to produce plants which make very rapid early growth, even when sown in Britain; and it is widely held that certain strains of Red Clover grown near the sea in England produce exceptionally vigorous plants, even when the seed so harvested is sown inland. It is not at all unlikely, therefore, or unscientific, to suppose that seed for different purposes should be harvested in different localities, and I think this assumption is not opposed to modern Mendelian teaching, for Mendelian characters are in many cases "strong potentialities" rather than absolute characters. For instance, you breed a Sugar Beet with a strong potentiality in favour of a high sugar content—the amount of sugar will to some extent depend upon the conditions of soil and climate; and if the potentiality for earliness is affected by the conditions under which a parent seed matured and was harvested, I cannot see why other potentialities, for instance the potentiality for rapid colonization in herbage plants, should not be similarly affected.

It must not be thought, because I have been so insistent on indigenous plants, that I would, therefore, deem locally exotic or even truly exotic species valueless for the ley. The success of Chicory on limeless soils in districts where this plant is never found wild shows how useful locally exotic plants may be, while the value of Lucerne in many districts exemplifies the importance of exotic herbage plants. It is interesting to note, however, that when plants other than those which are locally indigenous are used in temporary leys, it is nearly always necessary to sow in considerable amounts, in order that they may rapidly establish themselves.

Careful trials should always be conducted on a small scale with plants exotic to a locality before they

are relied upon for sward formation; and, although we are undoubtedly dependent on indigenous varieties (improved if possible) for rapid sward formation, no endeavour should be spared to hunt the world for untried species or varieties to add nutritious bulk to the herbage, or for the purpose of crossing with our local species or varieties. One genus in particular, I think, holds out considerable promise, and that is the genus Vicia. We have, of course, a number of perennial Vicias in our own flora—*V. Cracca* being not at all an uncommon plant on some types of grass-land. On the Continent and in America, moreover, there are several species of Vetch other than *V. sativa* used in agriculture. *Lathyrus* is another promising genus for investigation, both *L. pratensis* and *L. montana* being useful indigenous herbage plants. Attention should not, however, be confined to the Gramineæ and Leguminosæ alone, but other natural orders which contribute to the flora on old and semi-natural grass-lands should be made to yield new and improved strains of plants. The Rush and Daisy families immediately suggest themselves. It is perhaps not generally known that the *Juncus Gerardi* on salt marshes, *J. articulatus* on wet pastures, and even *J. squarrosus* on mountain pastures are readily eaten by stock; whilst, turning to the Compositæ, Chicory and Yarrow are pasture plants of proved merit. A more perennial Chicory and a less woody Yarrow would, however, be desirable, and one day, perhaps, we shall produce a strain of thistles which will be eaten as readily by cattle as our present spiny species are devoured by donkeys; and it is quite likely that all that is necessary is to produce a thistle without the spines. To go beyond these orders, Rib-grass is undoubtedly a nutritious plant, and is relished by stock (especially sheep), and will produce keep on the

poorest sandy soils where almost everything else fails. I have seen large flocks of sheep on fields sown with Rib-grass doing excellently in dry parched seasons when adjoining fields have been almost devoid of herbage. Rib-grass, however, does not produce enough leaf in proportion to its hard flowering stems, and it also produces excessive amounts of seed, neither seed nor stems being eaten by stock. Cannot these defects be bred out of Rib-grass?

I now come to the last point that I wish to discuss in connection with the relative value of a ley and old permanent grass, and that is the rival merits of the hay. Meadow hay is held in high esteem by farmers, especially for animals doing hard work or in illness. The value of meadow hay undoubtedly turns upon its complexity. It consists of the herbage from innumerable species, some of which will be more mature than others at the time of cutting, and all of which will have different coefficients of digestibility and nutritive value. The bulk will, therefore, form a more or less blended and well-balanced ration, being, as it is, the product of metabolic processes in various stages of completion, as well as of a number of species with inherently different ultimate chemical properties. Meadow hay is, in short, the "bread-and-butter" of feeding-stuffs; it has excellent feeding value. Excess of the one can be given to an animal and excess of the other to a child, and neither child nor animal can do itself much harm. Both feeding-stuffs are in fact "fool proof", and require no great skill or knowledge in their use.

Ley, or Seeds Hay as it is generally called, is in practice far from well balanced, the clovers making it excessively nitrogenous relative to meadow hay, and the number of gramineous species is generally few. It has therefore, in the economy of the farm, to

be balanced with other and appropriate feeding-stuffs, which implies both the possession of the other feeding-stuffs and a proper knowledge of their composition. In times of shortage, therefore, the best-informed farmer in the world may find himself in grave difficulties unless he has supplies of meadow hay to draw upon. With a little more knowledge it should, however, be quite easy to produce the absolute equivalent of meadow hay from a young ley. For grasses and clovers produce new and fresh herbage every year, be the individual plants two years old or twenty years old. It should therefore only be a matter of decreasing the clovers (which can always be done on certain fields) and establishing a sufficiently heterogeneous herbage on your ley, and it is largely for this reason that we want to introduce strains of Meadow Fescue, Meadow Foxtail, and other grasses capable of rapidly establishing themselves. There is, however, little or no accumulated knowledge as to the relative digestibility and palatability of herbage plants, and just as we know to a marked degree what simple feeding-stuffs are complementary to each other, so we want to know what herbage plants are complementary to each other.

I will now conclude my lecture by referring in a little more detail to the practical side of farming on the temporary-ley basis in order that the real significance of the theory of the temporary ley may be appreciated. I must again insist, therefore, that the adoption of this method of farming means far more than putting a few casual fields down to a temporary ley. My argument is in favour of converting our grassland districts into arable districts—but not arable on the old four-course rotation lines. It would be arable with grass as the pivoting crop, and so designed that a part of the farm, large in proportion

to the average rainfall, would at any particular time be under productive leys, which leys would move about in an ordered sequence over the whole farm. The rotation would be very elastic, the guiding principle being to break up all the leys while they were still fertile and full of clover. It is important in this connection to realize that in many districts fields can be successfully re-seeded down to grass immediately they are broken, and without being put through a rotation in the old sense of the word. I was, in conjunction with my friend Mr. Stanley M. Bligh of Cilmery, Builth Wells, engaged with experiments on these lines when the war broke out, and it was found that seeds mixtures could be put down with excellent results on a newly-ploughed turf under a crop like rape, or under a single corn crop. It is also a fact that the number of arable crops that succeed to perfection on a newly-ploughed turf is by no means limited. For, as well as oats, the potato, and frequently wheat, we have neglected crops like linseed and rye, forage crops, such as rape, and even roots; for instance, the yellow turnip often produces normal crops from a newly-broken ley. Wire-worm is probably the greatest difficulty to be contended with, but it is doubtful if wire-worm is as bad after short-ley turf as after older turf; and, in any event, agricultural science is likely soon to rise superior to the wire-worm.

Whatever view may be taken by competent agricultural reformers as to the rival merits of arable and grass-land farming, the war has taught us that our systems of farming should be flexible, so that altered methods may quickly be adopted to meet altered conditions. The outlook for the future is so complex and uncertain that nobody can prophesy with any degree of accuracy what food-stuffs it may be in the

national interest for farmers at home chiefly to concentrate upon producing a few years hence, and still less what the country's needs may be a decade or a generation later. The nation that can devise a system of agriculture, therefore, that can be rapidly made chiefly subservient to any sudden and unforeseen or unforeseeable need, without at the same time disorganizing the industry, is the nation which will achieve permanent and lasting security against food shortage. Our old and inelastic system of farming, on the basis of orthodox arable rotations which were deemed to be the corner-stone of good farming and inviolate, and milk and beef production on permanent grass-land, has broken down under the dire necessities of the times.

At present systems of farming may almost be said to be in abeyance, but the future of agriculture largely depends upon the evolution of new, and, as I have said, more flexible systems. It is to be hoped, therefore, that agricultural science will devote more and more attention to the broader aspects of farming, in order to be in a position to give the cultivator a definite lead in the matter of making the best possible practical use of the results of recent researches on the problems that underlie production. It is obvious that, as our knowledge of these problems advances, rotations and systems of farming evolved without the aid of exact science must be replaced by systems perhaps as fundamentally different from the old as are modern methods of locomotion from those of our grandfathers.

R. G. S.

SPRAYING PROBLEMS

Why has the question of spraying become of such prominence to-day that it is numbered among the biological war problems to be discussed in this series of lectures? Spraying, as everyone knows, especially when conducted on a national scale, entails a demand for supplies—supplies of machines, chemicals, labour, &c., at a time when the nation needs to economize—why, then, does the production of these things come under the category of the essential war industries? Since the nation was as wholly unprepared for extensive spraying as it was for the infinitely larger schemes of conscription and food rationing, the reason must be a sound one.

The answer is readily given: spraying is, in the first instance, an important means of obtaining an increased production of food, and, in the second place, it greatly assists to economize our produce.

Spraying is a means of attack used in the war against pests of animals and plants. These pests are numerous, and attack nearly every kind of plant, but their ravages naturally become most serious where plants of one kind are aggregated, as in the case of crops and orchards, since here the conditions are most favourable for epidemics. These pests, in their quest for food, often cause immense damage, and through their persistent and repeated raids the cultivation of certain economic plants in several instances has been abandoned.

A classic example is that afforded by the ruin of the coffee industry in Dominica and Ceylon.

In 1841 78,685 acres were under cultivation for coffee in Ceylon. From 1855-82 coffee was the staple export industry of the colony, reaching the maximum in 1875, when almost 1,000,000 hundredweight of coffee, valued at over £2,000,000 sterling, was exported. About 1870 the plants began to be noticeably attacked by a fungus, *Hemileia vastatrix*, the coffee-leaf disease, which spread steadily and irresistibly over the vast sheet of coffee plantations in the mountains, and was disregarded until too late. By 1880 the industry was threatened and the planters in great distress; it soon collapsed utterly. Not only did this react on the customs and rail receipts, but indirectly it ruined more or less subsidiary industries which depend on planting, and impoverished thousands of natives of all classes, as well as the planters and the mercantile community of Colombo, who are mainly dependent on the trade created by the planting industry. Ceylon has now ceased to be a coffee-exporting country. Some years previously the coffee industry in Dominica had been wiped out by this disease.

In a national emergency we can deal only with the most insistent and troublesome pests injurious to the production of vital economic products. During the war two plagues of vegetable life have come into prominence through the destruction caused to food. First, the plague of caterpillars and other insect pests which for two years in succession has caused havoc in the fruit-farm and orchard, and, second, the dreaded blight of potatoes which followed the introduction of the potato plant to Britain by some three hundred years.

The first serious onslaught of this disease, which swept over Europe with dramatic suddenness, has

left a grim page in the history of these islands. In 1845 Sir Robert Peel received an account in August of an extraordinary appearance of the potato crop in the Isle of Wight; these signs were soon observed throughout the south-eastern counties. The crops were almost entirely destroyed. Alarming accounts were received from Ireland, where the potato was almost the chief article of food and the means of obtaining other food. Dr. Lindley and Dr. Playfair were sent to Ireland to investigate the malady. Indian corn to the value of £1,000,000 sterling was sent to alleviate the distress, without avail. The great potato failure of 1846 brought in its train ruin, starvation, and death to many thousands. It has been described as one of the greatest calamities which ever afflicted the human race.

Through the allotment movement of 1917 the men and women of Britain became amateur gardeners and cultivators of the potato. The present year brings with it the prospect of an extensive use of potato flour. The production of 6,000,000 tons of potatoes is aimed at. The risk of serious loss through an epidemic of potato blight is correspondingly increased at a time when we cannot afford to take risks, at a time when it is imperative to reach high-water mark in food production.

The methods adopted in fighting plant pestilences are somewhat analogous to those used in actual war. The parasite must be attacked at a vulnerable point or moment.

In the case of a "naked" aphis, your spray compares with rifle and machine-gun shooting, except that the insects are killed either by suffocation or poisoning.

Again, in the case of the limpet-like San Jose scale, and other insects which pass the winter as a young

half-grown scale, the spraying compound must contain an ingredient capable of dissolving the wax which cements the scale to the leaf. Once the defensive armour is penetrated, the spray poisons or asphyxiates, as the case may be.

Caterpillars, when migrating, are stopped by a trench, which may be made impassable. Otherwise, soil insects, being underground, cannot be reached by "shell-fire", but must be gassed by injecting or mixing with the soil some substance such as carbon bisulphide or naphthaline. Beetle-borers, in their labyrinthine "dug-outs", may be attacked by spraying with a compound which gives rise to an asphyxiating gas, and gas masks have to be worn by those who apply the spray—as in spraying the roof of Westminster Hall. Certain insects, such as conifer-feeding sawflies, cannot, as a rule, be touched by sprays; these may perhaps be controlled by winged parasites—aeroplanes!

Consider first of all the remedies to be employed—our munitions, as it were, in this mimic warfare.

At a time like the present it is best to choose certain general preventive remedies to check the more troublesome pests: lime-sulphur winter washes for fruit trees to check fungi or insects awakening from winter sleep; mixtures containing lead chromate or lead arsenate in spring to protect fruit trees from greenfly and caterpillars; and an efficient fungicide. Curative treatment is useless in the war against potato blight. Unlike the American gooseberry mildew, which simply adheres to the skin of the plant, potato blight is caused by a parasitic fungus, *Phytophthora infestans*, known in 1845 under the name of *Botrytis infestans*, which actually effects an entry into the plant, absorbs food, and in the act of doing so poisons and destroys the tissues. The conidia or the

zoospores liberated therefrom germinate on the leaf; the germ tube enters a stoma and a fine weft of mycelium adpressed to the cells grows into the air spaces and absorbs nourishment from them. Within forty-eight hours aerial spore-bearing threads grow out from this internal spawn-weft, branch sparingly, and bear conidia at the tips of the branches. The conidia soon become detached, and are capable of infecting neighbouring leaves or plants. Since myriads of these conidia are formed on each diseased spot, the chance of infection is great, and when conditions are favourable it is easy to understand how rapidly the epidemic spreads. As if touched by some magician's wand, the aspect of the whole country-side changes from green to brown and black, and within ten days, in severe cases, there is nothing left but a waste of rotting vegetation. If the disease run its course the haulm perishes, and from that time forth tuber development is arrested. In the Kingsbridge and Barnstaple districts of Devonshire the haulm in early, mid-season, and late varieties was dead before the end of July, 1917, rendering a serious loss in the yield inevitable. If we can prevent this loss, which exceeds, on an average, 2 tons per acre, in disease-prevalent areas we have increased food production, or, if a certain tonnage of potatoes were required, there would be a commensurate economy in land and labour which could be utilized for other crops.

Potato blight can be prevented by spraying with Burgundy or Bordeaux mixture. These remedies were first used in France. It was the practice to dust the vines along the tracks through the vineyards in France with a mixture of copper sulphate and lime to prevent theft. It was observed that the powdered vines retained their leaves, whereas the leaves of vines not so coated were destroyed. Mil-

lardet took the matter up, and published results in 1886. About a year later mixtures were devised wherein washing-soda was used instead of lime. The use of these washes rapidly spread throughout Europe, and they soon became recognized as fungicidal remedies of the utmost value. No time was lost in adopting Bordeaux mixture to combat potato blight, and later it was used against various fungal pests of fruit trees in the United States, Canada, Australia, and elsewhere.

Burgundy mixture is now more generally used, since it can be made of more constant composition, and free from gritty particles, which choke the nozzle and exert a wearing effect on the working parts of the spraying machine.

Burgundy mixture is produced by the interaction of copper sulphate and washing-soda, and only standard chemicals of guaranteed purity should be used. Copper sulphate is a virulent plant poison, so much so that a 1-per-cent solution is used for charlock-killing, and a 1-per-cent solution of this sort alone would prove deadly to the potato. The copper sulphate is just neutralized when the chemicals are mixed in the proportions of their molecular weights, but it is better to use an excess of soda to obviate the risk of obtaining free copper sulphate.

The product of the reaction, copper carbonate, varies in physical qualities according to conditions; for example, in adhesiveness, specific gravity, and texture. The best results are obtained when the chemicals are mixed in cold solution, forming a more adhesive compound at lower temperatures, and when the solution of soda is added to a weak solution of copper sulphate, since in this case the precipitate is more flocculent and evenly distributed throughout the liquid.

The rôle of Burgundy mixture is roughly analogous to the use of a shrapnel screen put up to prevent hostile aeroplanes from reaching the metropolis. The barrage protects London: so the chemical "barrage" protects the potato plant.

The copper carbonate, or Burgundy mixture, is insoluble in water and non-poisonous to plant life. When once allowed to dry on, the heaviest rains will not remove the deposit. To return to our illustration, the more perfect the barrage the less chance there is that the hostile machines will reach London. Again, it is useless putting up the barrage after the machines have reached their destination. So with Burgundy mixture, if the plant is to be thoroughly protected, it must be efficiently covered, and covered before the blight makes its appearance.

The question naturally arises: How does this non-poisonous coat prevent or kill the germs of potato blight? Barker has found that the fungus in germinating excretes a vegetable acid which reacts with the chemical film to produce a soluble salt of copper; this soluble copper poisons the growing germ tubes. In the case of the American gooseberry mildew, the mycelium takes a green coppery stain, proving the release of soluble copper.

Spencer Pickering states that the carbon dioxide present in the atmosphere reacts with the film of Burgundy mixture to produce soluble copper. Besides carbon dioxide, various impurities present in the atmosphere in the neighbourhood of manufacturing areas, chemical works, kilns, &c., when brought down by rains, are probably capable of releasing soluble copper, and producing it in sufficient quantity to cause injury to the host plant.

Recent cases of injury through spraying are chiefly from manufacturing areas or allotments in the neigh-

bourhood of cities, where, incidentally, the conditio are prejudicial to the health of the plant. Everyo who has visited the Chelsea Physic Garden a fe weeks after the young growth has unfolded in spri will have noticed a fine black carbonaceous film co ing the foliage. The yellowing of the potatoes gro in front of Buckingham Palace, which had commenc before the spraying operation in July, was attribut in part to the petrol fumes and exhaust products d charged from the numerous motor-vehicles passi within a few yards of the potato plots.

The injury caused to plants by aphides is oft emphasized by spraying. Perhaps soluble copper formed through the action of the saliva or excremen and this may penetrate the epidermal and subjace tissues through the punctures made by the insec proboscis. It must be remembered, however, th unsprayed plants attacked by aphides will frequent succumb after a few days' heavy rain.

Some curious cases of injury through sprayin were reported by the Lancashire County Coun authorities in 1914. It was thought that certain co ditions which tend to check vigorous growth predi pose the plants to spraying injury.

The whole question is very obscure. It shou be studied experimentally by trials conducted in t neighbourhood of factories, on sites where aphides a prevalent, and on farms where the effect of sprayir under diverse conditions could be carefully inves gated.

Burgundy mixture should be regarded in the lig of an invention which needs to be perfected, just we may improve and refine other articles of com merce, aiming at securing increased economy chemicals, labour, and cost, without in any wa impairing the fungicidal power.

Economy of labour might be effected if we could devise a spray ready for use, thus obviating the process of mixing ingredients. Several commercial ready-made spraying compounds have been invented which are said to fulfil this requirement, but none equal in efficiency freshly-prepared Burgundy or Bordeaux, since they do not retain the valuable adhesive properties which are obtained when these mixtures are freshly prepared. When used as a dry spray in districts where disease is habitual and severe, more sprayings appear to be necessary in order to produce the same fungicidal result as that obtained when using Burgundy. Hence the advantage gained through using a single compound is lost, and an adverse balance remains through the labour and time involved in increasing the number of spraying operations.

Commercial efforts have been made to supply Burgundy mixture prepared as a single powder, but such powders contain a substitute for washing-soda; actual mixtures of copper sulphate and washing-soda have not yet proved satisfactory, since the mixture tends to deteriorate.

Copper sulphate of 99-per-cent purity can now be obtained in powder form. This preparation should supersede the old bluestone crystals, owing to the rapidity with which the powder dissolves in cold water. If we could find an efficient substitute for washing-soda—and several substitutes have been suggested—either in the form of a powder or small crystals that would not react either physically or chemically with the other chemical ingredients, the problem of a one-powder Burgundy mixture would be solved.

Probably the best way of improving Burgundy is to increase its wetting power. Liver of sulphur dissolved in water was formerly used a great deal in

combating mildew, and usually with little success. This is not surprising, since the liquid possesses a low wetting power, and when applied to plants with shiny foliage, such as Wichuraiana roses, or covered with a waxy coat, as in the case of carnations, it rolls off in droplets. Moreover, owing to the physical characters of the felt-like mycelial skin formed on the plants by such fungi as the American gooseberry mildew and rose mildew, the mixture does not wet the fungus, and hence does not penetrate nor kill. But add a soap, and the efficiency is at once increased through the improved wetting power. Soapy mixtures in which the amount of liver of sulphur is reduced to $\frac{1}{8}$ ounce per gallon have given results equal to those obtained when using a $\frac{1}{2}$-ounce-per-gallon solution in water. The wetting power of Burgundy mixture can be considerably increased by adding milk or soap powder. One-quarter and one-half per cent soap-Burgundy will not only prevent the appearance of the American gooseberry mildew, but kill the perithecia without bringing about the defoliation caused by using stronger solutions. If we can reduce the strength of Burgundy mixture, a considerable economy in chemicals is effected; against the economy in chemicals must be set the cost of the soap, but it should not be difficult to find an inexpensive soap, which would bring down the cost of the mixture.

Burgundy mixture can be modified to suit different needs. A 2-per-cent solution once applied in February will prevent peach-leaf curl due to *Exoascus deformans*; a 1-per-cent solution will stop leaf-spot of celery due to *Septoria Petroselini*; a 1-per-cent lacto-Burgundy will check carnation rust; a $\frac{1}{4}$-per-cent soap-Burgundy will prevent delphinium mildew without disfiguring the flowers. Other special mix-

tures are suitable for apples and pears against scab and apple-fruit spot. In Burgundy mixture we have a remedy capable of almost universal application against fungal pests.

Let us turn for a moment to the implements or artillery used in the war against fungus pests. Just as the aeroplane, from the simple machine used by the immortal Blériot, has assumed astonishing development and specialization, so from such humble beginnings as the heather brooms used by the peasants in Ireland, and from various simple syringes, machines of a most complicated character have been evolved and adapted to suit the special needs of the agricultural and horticultural sections of the community.

In the early days of hop-washing, machines of the hand and knapsack type were the only ones used in hops, but as the blights became more severe, and there was danger of losing the greater part of a crop unless washing were carried out quickly and expeditiously, the horse-drawn automatic spraying machine was evolved.

This machine consisted of a tank on wheels with the pumps driven from the axle, and the wash was delivered under pressure to the nozzles situated round the machine and directed so as to wet completely everything around it as it was drawn along the hop alleys.

Hop-washing machines were strongly constructed, and were fitted with pumps capable of delivering the spray at a fairly high pressure.

The experience gained in hop-washing proved of considerable advantage when fruit-tree spraying came into practice, as the machines were at once able to spray successfully the fruit trees, getting through to the under sides of the leaves in all parts of the trees.

About this time, too, as spraying requirements became more general, power-driven spraying outfits were designed for spraying over large areas from a central mixing station. These plants, besides the necessary engine and pumps and mixing plant, required the laying of some miles of piping and involved the outlay of some thousands of pounds.

These outfits, of course, required the use of still stronger pumps, as a pressure of 200 to 300 pounds was necessary to ensure the requisite pressure of about 100 pounds at the point of delivery, the nozzle.

A further development occurred a little later, when the horse-drawn, hop-washing machines were fitted with motor engines for driving the pumps, whilst one or two horses drew the machine along.

These machines have now been introduced for use in young orchards, the waste of spraying mixture between the trees being more than compensated for by the great saving of time and the resulting ability of the grower to combat quickly any attack of pest.

One of the principal developments in spraying has, however, been in the nozzle. In the early days the usual thing was to drill a fine hole or two in a pipe or nozzle end, and this was constantly choking up; in fruit-tree spraying a very much finer spray was required, while it was necessary, owing to the varying kinds of spray fluids to be used, to have a comparatively large aperture in the nozzle, so that everything which would pass the strainer would come out of the nozzle. Nozzles were consequently constructed so as to impart a rotary motion to the fluid and with a simple means for controlling the proportion of rotary to direct action, nozzles were produced which could be set to give any character of spray to suit all kinds of requirements. The nozzles now produced are as

near perfection as possible with one exception, and that is, that all of them give off a circular ring of spray and leave the centre untouched, so that it is yet open for someone to construct a nozzle which will also hit the centre and give an even coating over the area at which the spray is directed.

Many new developments of the spraying machine are foreshadowed, and possibly one of the first types to appear in the near future, now that motor tractors have been generally adopted, will be a tractor sprayer.

The tractor sprayer will consist of pumps and tank mounted together on a light motor having suitable travelling wheels, the pumps being driven from the engine and the tank fitted with an automatic agitator to keep the mixture well stirred. This machine could be fitted with a set of delivery pipes somewhat like the present hop-washer, so that the trees or plants could be sprayed as it travels along between the rows, or the same machine could be used in connection with several short lengths of hose with branches and nozzles for hand-spraying purposes, the machine being driven from tree to tree as each is thoroughly sprayed.

For potato spraying it is quite likely that some form of motor will be evolved if the difficulty of steering can be properly overcome. With such a machine it would be possible to deal with a much larger acreage in the same time.

Let us refer to the potato disease once more, to see why it is necessary to spray universally. After the disease had attacked the foliage, the old story was that the fungus passed down the haulm and reached the growing tubers. This view is proved to be incorrect. The myriads of spores formed on the foliage are scattered by the wind not only on the neighbouring plants but on the ground. Should there chance to be

wet weather late in summer or in early autumn, according to the county or season, conidia are washed down through the soil to the surface of the tubers, and can penetrate the skin, just as they can the green leaves, and bring disease. In this way there is a further loss to the crop through disease. It was said many times last year that diseased potatoes do not matter: they can be used to feed pigs. In 1845 diseased potatoes were used for potato flour, but the quantity yielded by the diseased potatoes is less than from sound potatoes, although the quality does not appear to suffer—the flour is a little darker in colour but in no degree unwholesome. At a time like the present we want the utmost return from our efforts: from the figures published by the Commission for the Relief of Belgium there is a difference between the energy secured from a pound of European and American potatoes in good condition, being 78 calories in favour of the European, a difference equivalent in caloric value to the energy obtainable from an egg of medium size. If this is the case, there would surely be a considerable loss in energy from an equal weight of diseased potatoes, and the feeding value, even when used for pigs, would be exceedingly low. From what we have said, it will be seen that a man who has carefully and thoroughly sprayed may obtain disease through the neglect of his neighbour, or a careful community from that of one careless one. The more disease is prevented from appearing the less risk there is of serious loss. That is why we should aim at universal spraying, spraying the garden of the palace as well as that of the humblest cottager. That is why, last year, premier and peer, plotholder and peasant, shouldered knapsack machines and learnt to spray.

In a campaign many problems confront one: how are we to reach all sections of the community, to provide

motor sprayers for the large farms, horse sprayers for the small; to help the smallholders and the thousands who had never sprayed at all? To meet the emergency last year the Food Production Department distributed 7000 knapsack sprayers and 40,000 cases of chemicals to public bodies and individuals.

Many plans were devised on the spur of the moment; each hamlet, village, and town had a problem to solve; some solved it remarkably well and others not at all. It wanted organization, forethought, and skill. In some cases the villagers clubbed together to purchase their own material, and each man sprayed his own; in others the squire or parish council or the allotment association made the provision of the requisite implements and labour; in other cases borough councils provided the implements and made no charge for labour. To-day and to-morrow we must aim at economy in material and labour. In the main two systems emerge: the co-operative system, where individuals band together, take the initiative, and share the expense; and communal, where everything is done for the community and a charge placed on the local funds.

The greatest hope for the progress of the spraying movement among allotment holders and smallholders generally seems to be in the development of communal spraying. This might be carried out in the future by a motor equipment. Just as a municipality possesses a fire-station and every appliance for combating fire, county councils or municipal authorities might erect a central mixing-station where barrels of Burgundy mixture could be prepared, and these and the necessary sprayers taken to the different allotment grounds, allotted areas, or farms—the equipment to be employed for bush-fruit and small fruit trees for both summer and winter spraying. Special outfits

could be added for large orchards and for other purposes to fulfil local requirements.

In a campaign it is important to know the disposition of the enemy, habits, movements, &c.; so in a campaign against disease we should possess full knowledge of the organisms influencing the appearance and spread of an epidemic and the conditions causing it. Malaria could not be controlled until we understood that the mosquito acted as a carrier, nor typhoid until we had discovered the different types of bacilli found in enteric fever. In the case of potato blight, if *Phytophthora infestans* can only pass the winter in diseased tubers, it should be possible to eliminate the malady by selection of sets. But are we sure that this is the only method of wintering? Phytophthora can be grown easily on artificial media, and, if so, may be capable of existing saprophytically in the soil. Again, if potato disease appears in early summer at only a few centres it would be possible to isolate the outbreak and control it by the "ring-fence" method; but if, on the other hand, there is a simultaneous outbreak at a large number of places it is important to spray wide areas. From the evidence at our disposal, disease is most severe in Ireland, the south-western peninsula, western Wales, and south-western Scotland, regions more or less under the direct influence of the Gulf Stream. The earliest outbreaks in 1917 occurred in the Isle of Wight, Fishguard, and the Penzance district, in coastal districts of low elevation and subject to sea mists and fogs. The direction of the development of the disease appears to have been roughly fan-wise towards the east, north-east, and north. It corresponds in a remarkable way with the progress of the great murrain in Scotland. In 1845 the disease was first observed in the south-western counties—Wig-

town, Dumfries, and Ayr—in July, and there is a record which gives the first week in August for the Island of Islay (Hebrides). The records for Argyll, Linlithgow, Renfrew, and Fife—counties to the north or north-east—are not earlier than the middle or end of August. In Perthshire, farther north, and Haddington, to the east, disease is not recorded earlier than September, whilst it is stated to be unknown in Inverness, Aberdeen, Elgin and Moray, and Caithness.

The course taken by the epidemic in England is perhaps determined to a certain extent by the somewhat zigzag valleys of the Wye, Severn, Trent, Welland, Great Ouse, and Thames, which radiate in fan-wise direction towards the east, north-east, and north when viewed from the Severn estuary. These valleys, subject to mists and fog, would prove ideal channels along which the disease, helped by prevailing southerly and south-westerly winds, could spread over the country-side.

It has to be remembered that the direction of development east and west also corresponds to progressive seasonal lateness. The fact that there is an interval between the attack on early and late varieties seems to indicate a period in the life-cycle when the plant is more susceptible to the disease. If this were the case disease would appear progressively later from the south-west and west to the eastern and northern counties.

If an outbreak of disease occurs in the present year, it may be expected to take the same general course; but its date of appearance and degree of severity may vary considerably. For example, in 1917 disease was comparatively light in the counties of Cheshire and Lancashire, and did not make its appearance until the end of the third week in August; in 1845

it prevailed earlier and to a more serious extent in these counties.

Many questions have been asked as to whether, if the disease be a disease of middle age, we cannot evade blight by a choice of suitable varieties, or adopt some ruse such as late planting or planting early varieties only in districts where blight is late, and thus tiding the plant over the probable time of fungal activity; or, again, whether certain methods of manuring, certain soils, &c., render the plant less liable to attack. The experience of the last seventy years has shown that a suitable land, a happy sequence of weather conditions, correct manurial treatment, and good cultivation ameliorate but cannot prevent the pestilence; it may be because we can rarely hope to obtain ideal conditions. Spraying has been adopted for these very reasons. The State requires immense supplies, and to meet the demand potatoes must be grown wherever possible. Since, however, we aim at economy of effort, everything good husbandry can do should be done to reduce the risk of disease. In 1845 considerable attention was given to the conditions of weather, soil, soil treatment, and susceptibility of varieties in relation to the murrain, and very numerous and valuable observations were made. To-day, possessing, as we do, a more accurate knowledge of *Phytophthora infestans*, and equipped with an efficient weapon, we should make an effort to settle some of the problems which baffle the grower and react in the end prejudicially on the practice and purpose of spraying.

These various factors could be analysed by conducting numerous trials on farms and allotments, especially in those counties where disease is usually severe, and by tests in experimental gardens, where the more technical questions could be studied.

The method of outbreak and spread of the disease could be studied by systematic observation, deciding beforehand on the localities or actual sites to which special attention should be given. The trial stations and observation sites could be linked together to form a system for England and Wales, which would take into account the most important hill and mountain systems, follow the coast-line and course of the more important river valleys and cross-tracts of land having any special soil characteristics. Thus in Cornwall attention could be given to the moorlands and intervening lowland, to the influence of the sea in the north-western, southern, and south-western aspects, the River Fal and its estuary; in Wales, where detailed rainfall maps have been prepared by the University authorities, the outbreak could be followed in relation to the rainfall; or the epidemic in a county like Montgomeryshire, where the soils are mainly clays, could be compared with the outbreak in Pembrokeshire, where the geological structure is extremely varied.

Besides bringing home to the general public the advantages of spraying and the necessity of producing untainted crops, the economic advantage to the country would be considerable. Each county, and even district, could form its own spraying time-table, and know within certain limits when and how often to spray and with what strength of solution, and could organize its available sources of labour to the best possible advantage.

A. S. H.

BIRDS AND INSECTS
in Relation to Crops

Among the mighty efforts now being made by the nation for the maintenance of our Empire in time of war the attempt to increase the production of food is one that has engaged the serious attention of the legislature, and has made increasing demands upon our physical and scientific endeavours.

The destruction of our food-supplies by the action of the enemy at sea has been met by the determined resistance of our Navy and our armed and unarmed merchantmen; but, unfortunately, the destruction of our food-supplies by our enemies at home—the birds and the insects—has not received the serious attention it deserves, nor has it been the subject of intense and co-ordinated scientific effort.

If one calls to mind the damage caused to various food crops during the summer of 1917 by insect pests, such as the wire-worm, the wheat bulb fly, the cabbage-root maggot, the onion and carrot flies, and the caterpillars of various species, it is probably no exaggeration to say that the insects alone destroyed more of our home-grown food than the submarines of our enemies destroyed of the food that was to come to us from abroad.

There seems to be an idea that whereas the destruction of ships at sea is an act of the enemy which can be countered by naval action, by guns and by shells,

the destruction of our food crops by birds and insects is an act of God, to which there is no available counteraction in the hands of man. But although at the present time we have no effective protection against the ravages of the most prevalent bird and insect pests, the wonderful results obtained by skilled scientific investigation, particularly in the United States of America and in Canada, encourage us to believe that if we can only bring to an end our long national neglect of science, the destruction of food crops by our home-grown enemies may be, to a very great extent, prevented.

Of the two classes of animals—the birds and the insects—which provide the farmer with his principal destroyers, it might seem at first sight that the former could be kept in check the more readily by the direct method of attack, that is to say, by shooting the birds and destroying their nests, and that the problem does not present any insuperable difficulties. Some of our birds, such as the wood-pigeon and the sparrow, which feed almost entirely upon seeds and plants, are regarded as being wholly destructive; other birds, such as the tits, fly-catchers, martins, and others, being insectivorous in habit, are regarded as wholly beneficial. Every effort should be made, therefore, according to prevalent views, to destroy the wood-pigeons and sparrows, and to preserve and foster the tits, fly-catchers, and the martins. But many of our most common species are known to be omnivorous; they will take grain, and they will destroy root-crops of various kinds, but will also devour large numbers of the most pernicious insect pests, and in these cases it becomes necessary to determine by the evidence of the food they have actually swallowed whether the benefit they confer by the destruction of insects does or does not exceed the damage they do to the seeds

and crops. To deliver a true verdict on the evidence that may be collected as to the food of any one of these omnivorous birds is by no means an easy matter, because the food varies in different months of the year, and even in the same month in different parts of the country. But a verdict that is based upon observations of the birds feeding at a distance in a field or upon impressions and traditional prejudices of the country-folk may be entirely misleading, and if it is followed by active measures, or the ruthless shooting down of the species, may lead to irreparable mischief.

In order to obtain some trustworthy evidence on this matter a committee was appointed by the British Association in 1908, and this committee, with the co-operation of the Board of Agriculture and with the assistance of grants of money obtained by the board from the Commissioners of the Development Fund, and smaller grants made by the British Association, undertook the scientific investigation of the contents of the crops and gizzards of our three most abundant omnivorous birds, the rook, the starling, and the chaffinch.

Reports on these investigations were published as a supplement to the *Journal of the Board of Agriculture* in 1916, but in respect of the work done in the University of Manchester, the report then published was only an interim report, the results of the investigation not being completed or fully tabulated.

To furnish the requisite material, a number of birds were shot by the correspondents throughout the year and forwarded to the investigators, who carefully examined and recorded the contents of the crops or (in the case of the rook) the gizzards. The animal food was classified into two groups: the insects,

worms, and slugs that are known to be injurious to the food crops in one group, and those that, by themselves destroying animal pests, are known to be beneficial. In like manner the vegetable food was divided into the seeds, leaves, and other fragments of food plants which were placed in one group, and those of pernicious weeds in another. I may remark that this part of the work required the co-operation of skilled entomologists and botanists, for it needs special knowledge to determine whether a fragment of an insect—a leg or a wing—belong to a beneficial or to an injurious insect, and to be quite certain that the small seeds found, particularly in the crops of chaffinches, belong to pernicious weeds or to useful grasses and food plants.

As a general result of these investigations it was agreed that, on balance, the starlings are beneficial to the farmer. It is true that they take some toll of grain; but it must be borne in mind that a great deal of this grain, being scattered in fields or around barns, would never be recovered for the farmer. On the other hand, they destroy so many insect pests, and possibly keep in check so many weeds, that they pay and more than pay for the grain food that they consume.

As a result of these investigations it may also be said that the chaffinch is a beneficial bird, as is shown in the following statement, the result of many years' accurate and laborious work, for which I am indebted to Mr. H. S. Leigh of the Manchester University:—

"By far the greater part of the vegetable food of the chaffinch consists of the seeds of weeds, the seeds of chickweed, knot-grass, and dock being in greatest abundance. Seeds of chickweed were found in almost every specimen from September to March. Seeds

of value to the farmer have only been found in a few instances (seven or eight). The insect food of the chaffinch is probably much larger than the records indicate, because so much of it is of such frail nature that it is rapidly destroyed. Many of the insect remains were very fragmentary, and therefore very difficult to identify; but it was found that from April to July many species of the destructive weevils (Rhyncophora) were taken, and many of the smaller species of lepidopterous adults and larvæ. It also takes adult craneflies, whose larvæ—the leather jackets—are so destructive to pasture lands and numbers of the larvæ of the winter moth (*Chimatobia brumata*).

In the case of the rook, however, there were differences of opinion. Mr. Theobald, who investigated the food of the rooks that were shot in the southern counties, declaring that this bird is more harmful than beneficial, and Mr. Leigh, who investigated the food of the rooks shot in the northern counties, returning a more favourable verdict on behalf of the bird. It is in my opinion very unfortunate that the committee was not summoned to consider these divergent opinions before the reports were issued, and that it should be left to the reader to form his own opinion from the summary of evidence laid before him.

It seems to me that the whole of the evidence points directly to the conclusion that the rook is a beneficial bird. If we proceed on the plan of balancing one grain of corn and one injurious insect found in the gizzard we find undoubtedly a verdict against the rook; but this method is to my mind entirely misleading. An injurious insect destroyed may mean many plants, not grains, of corn saved to the farmer. A grain of corn eaten by the rook may be a grain that would never have been garnered.

We should regard, therefore, the evidence of one of

these insects destroyed as balancing, not one, but many grains of corn, and on this reckoning the rook is decidedly beneficial.

Bearing upon this deduction, it may be pointed out that there is evidence in the reports that the rooks obtained large quantities of grain in the months of May and June, and this is reckoned in the adverse scale of the balance. Now where did they get this grain in the summer months? Until that question is answered satisfactorily, this corn ought not to stand as evidence against them. On the other hand, Mr. Leigh's evidence as to the destruction of wire-worms and leather-jackets by the rooks is most impressive. If, as he found, one rook will swallow 95 leather-jackets at a meal, and another 103 wire-worms, we can understand what an immense benefit these birds are to the farmer in clearing his fields of these most destructive insects.

It may be fairly argued from these reports that the case against the rooks has not yet been established, and therefore that the action of some of the county councils in encouraging the shooting of rooks on a great scale should be most severely condemned. What is really wanted is further information on the habits of the bird, and particularly on the food supplied to the nestlings. Such information we are not likely to get in the near future, for, with what we may regard as our national failing in clear foresight, the grants for the investigations have been withdrawn, and the work left in an incomplete and unsatisfactory condition.

Nevertheless, the collected evidence of these investigations does at least warn us of the danger of any scheme for the indiscriminate slaughter of these birds. It has shown that, although they take some toll of the grain both at sowing-time and at the harvest, they

must exercise an important control over the insect pests that destroy our corn and pastures, and that if this control is removed some other means must be found to check the increase of the wire-worms, leather-jackets, and other injurious insects.

Perhaps some day such other means will be found, but at present, for want of accurate scientific knowledge, we are practically helpless. The evidence concerning the food of the wood-pigeons has not yet been collected in a careful and systematic manner, but there can be little doubt that the popular opinion that this bird is almost entirely destructive is justified, and that organized efforts should be made to reduce its numbers.

The sparrow is also a bird that, during the greater part of the year, takes a heavy toll of human food in the agricultural districts, and is unfortunately so plentiful that the total amount of grain it devours per annum is a serious loss to the country. It is true that during the nesting season it carries many caterpillars and other larval and adult insects to its young,[1] but, for all that, systematic efforts should be made throughout the country to reduce its numbers. But for many reasons, moral as well as practical, the practice of employing children to destroy sparrows should be most sternly condemned. I will not discuss here the moral reasons, but indiscriminate awards of money offered to children for sparrows and the eggs of sparrows have led in many cases to wholesale destruction of such valuable birds as the hedge-sparrow, the robin, and the fly-catcher.

It may seem to many people that our efforts to control the ravages of insect pests in this country have not been very successful. Notwithstanding the sheaves of pamphlets issued by the Board of Agri-

[1] W. E. Collinge, *Journal Board of Agriculture*, XXI, 1914.

culture, and notwithstanding the laborious investigations of our entomologists, we lose annually millions of pounds' worth of food and timber by the destruction of our wheat, our roots, our cabbages, onions, carrots, and forest trees by insects.

But I would ask: Have we really made any serious effort to solve these problems? Our ignorance of the fundamental facts that underlie them is almost complete. We have no systematic records of the prevalence and distribution of insect pests, we have no reliable estimates of the damage that is done in successive years, we have no data upon which we can form conclusions on the relation of the severity of winter to the prevalence of insect pests in the following summer. We are working, in fact, almost entirely in the dark.

What is wanted in this country is an official entomological office or bureau which will collect and tabulate the records of responsible entomologists in all parts of the country on the prevalence of the worst kinds of insect pests. We want a staff of trained men, as they have in Canada and the United States of America, prepared to travel to any part of the country at a moment's notice to deal with a sudden outburst of a dangerous pest, and, when we have sufficient knowledge of conditions, there should be official warnings issued to farmers, similar to the meteorological warnings, as to the probability of the prevalence of pests in different districts.

It is true that the cost of such a bureau would be heavy, but I am convinced that both the initial capital that would be required and the annual expenditure is a trifle compared with the millions of pounds' worth of damage that is done every year to our food crops, and which can and should be prevented.

To illustrate the methods by which the control of insect pests may to some extent be effected two examples may be quoted, in which valuable economic measures have been the result of careful scientific work. The maggot of the fly *Chortophila brassicæ* is, in many parts of this country, very destructive of cabbages, cauliflowers, and brussels sprouts. There is evidence that in some cases the whole of the first setting of these plants has been destroyed, and in very many others that over 50 per cent of the plants have been either destroyed or seriously checked in their early growth.

It was found, on studying the natural history of the insect, that the adult female, which makes its appearance early in the month of May, approaches the young plants and lays her eggs on the ground close to the stem. Soon after the eggs are laid the young maggots emerge and burrow down into the earth to begin their attack upon the roots. If the plant is not already well established, and there are sufficient maggots present, the whole of the roots may be destroyed and the plant perishes; but if the plant is well established, or the maggots not too numerous, it may recover and suffer no more than a temporary check in growth. Now it occurred to Professor Tracey, of Detroit, U.S.A., that if a paper disk were placed round the base of the stem at the time of setting, the maggots would be prevented from burrowing down into the soil to attack the roots. As a result of several experiments paper was found to be unsuitable, and it has been replaced by squares of a coarse roof-felting.

The use of these disks proving to be extraordinarily successful in America, it was decided to try some experiments on their use in this country. Under the direction of Dr. Imms and Mr. Wadsworth a field

was selected in the neighbourhood of Manchester where the pest was known to be prevalent, and in one of the experiments four parallel rows of cauliflowers were set, with 233 in each row. Two alternate rows were protected by disks, and two were left unprotected. In August of the same year it was found that of the cauliflowers in the protected rows 5.1 per cent had been destroyed by the root maggot, and in the unprotected rows no less than 63 per cent had been destroyed. In the case of the cabbages, which are in this respect hardier plants, the results were not so striking, but still of the protected cabbages only 0.2 per cent in comparison with 13.2 per cent of the unprotected cabbages were destroyed.[1]

These results do not take into consideration cases of partial infection in which the plants recovered from the attack, and only suffered a check in their growth and full development.

In this method of control we are dealing directly with the insect that causes the damage, by interfering artificially with the conditions that are essential in a critical phase of its life-history. But it is advisable in all these cases of direct attack to study also the possibility of an indirect attack by way of the protection or encouragement of the natural enemies of the insect. Nearly all the insects that have been carefully studied are known to be destroyed in large numbers by their natural enemies. Insects are so prolific that without these checks which are provided by nature the world would soon be overwhelmed with insect life. And it seems very probable that the variations we observe in the severity of the attacks of insect pests in different seasons are due in large measure to the variations in the numbers of their natural enemies in the preceding season.

[1] J. T. Wadsworth: *Annals Applied Biology*, III, 1917.

Of these natural enemies the birds, the moles, the centipedes, and others play an important part; but, generally speaking, it is predaceous insect larvæ and parasitic insects that are most destructive of insect life. One family alone, the Ichneumonidæ, is responsible for the destruction of a very large percentage of some of the most virulent of our insect pests; in fact, it may be said that if, in this war that we are waging for the protection of our food crops, the Ichneumons were to make a separate peace with the enemy, we should be starved into submission in twelve months. It is important, therefore, in considering any proposed method for dealing with an insect pest, to find out what other insects are parasitic upon it, and to take into consideration the effect of the method on the insect parasites.

For instance, in some cases "it may be highly injurious and superfluous to apply insecticides, as they also destroy the beneficial insects which are already acting as a check on the injurious species".[1]

There is no reason to suppose that the disk method of protection would materially interfere with the beneficent work of the parasites of the root maggot, but nevertheless it was deemed necessary to obtain as much information as possible about the number and character of the insect enemies of this destructive pest. It was found that the most destructive insect that preys upon the root maggot is the predaceous Staphylinid beetle, *Aleochara bilineata*. It is not only the adult beetle that devours the root maggot, but it has now been proved that its larva bores into the pupa and destroys it.

The effect of this insect in reducing the numbers of the maggot of the Chortophila must be in some cases very considerable, as in one of the counts made by

[1] A. D. Imms's *Quarterly Journal Micr. Science*, Vol. LXI, 1916, p. 218.

Mr. Wadsworth, in 1914, no less than 26.9 per cent of the maggots were found to be thus parasitized. But the Aleochara is not the only parasite that destroys the root maggot, as it has been found that to a relatively small extent the pupæ are parasitized by two species of Ichneumons, and rather more frequently by a species of Cynipid fly.[1] Our knowledge of these parasites may not at present lead to any practical results, as the disk method of protection of the plants seems to be effective in most parts of the country; but where the disk method fails, as it is said to do in some districts, owing to climatic or other conditions, the introduction of Aleochara might prove to be an important means of checking the spread of the pest.

As an example of another method of attack upon a destructive insect, which, I venture to think, has proved to be efficacious, I may refer to the last outbreak of the larch saw-fly attack. The first notice that was received of the renewed activity of this destructive insect was in the summer of 1906. The larch trees in the plantations of the Lake District were losing their young shoots, the leaves were turning brown, and the year's growth of wood was evidently being checked.

As the outbreak was particularly severe on the hill slopes leading down to Thirlmere—from which lake Manchester derives its water-supply — Dr. Gordon Hewitt was entrusted with an investigation of the insect, and asked to suggest some remedial measures. It was found that an investigation of the natural history of the insect and its natural enemies would take some years to complete, and therefore it was suggested that in the first instance the Corporation

[1] J. F. Wadsworth: *Ann. Applied Biology*, II, 1915, and *J. Econom. Biology*, X, 1915.

should take some steps to encourage the birds that had been observed to feed upon the larvæ of the saw-fly.

The principal birds that were thus observed to be holding the insect in check were the robins, tits, and the fly-catchers. All these birds build their concealed nests in holes in the trees, and, as the trees of the district are mainly conifers, the supply of hiding-places was necessarily limited. It was therefore decided to put up a number of properly-constructed nesting-boxes in the neighbourhood of the larch plantations that were most severely attacked, and to feed the birds in the winter on protected feeding-platforms. This was done. Boxes of two sizes were suspended in the trees, and the number of boxes was increased year by year. At the end of the first summer the boxes were examined, and it was found that about 30 per cent had been occupied during the nesting season. This was considered to be a satisfactory result, considering the bird population of that beautiful but at the same time rather inhospitable district. But in the following year the percentage of boxes occupied increased, and the same in succeeding years, until in 1912 no less than 71 per cent of them contained one or more nests.

The result of these efforts was a noticeable increase in the number of birds in the district, and every year they waged a more intense warfare on the saw-fly. I do not think that there can be any reasonable doubt that as a direct result of these encouragements the number of tits, robins, starlings, and some other species of birds in the Thirlmere plantations was considerably increased. On this point our own observations were fully confirmed by the opinions of people living in the district who were well acquainted with the bird life before and after the boxes were provided, but the

following table supplies evidence of this increase, which is not based on simple opinion:—

Year.	No. of Boxes in the Woods.	Percentage of Boxes occupied.
1908	60	31
1909	174	46
1910	280	57
1911	347	66
1912	341	71

But, it may be asked, did the birds produce a noticeable effect upon the severity of the saw-fly attack? The answer of a man of science to that question must be cautious. We were attacking the saw-fly by means of the birds, but there were many other agencies working for us, as will be presently related, over which we had no direct control, and, to be quite frank, it cannot be proved to demonstration that the birds were the primary cause of the happy results obtained in 1912 when the woods were practically cleared of the saw-fly pest. It is significant, however, that, whereas in 1912 the Thirlmere estates were almost free from the saw-fly, the surrounding districts of Cumberland and Westmorland were suffering severely, and on the slopes of Skiddaw, within sight of Helvellyn, no less than 3000 larches were felled in 1913 on account of the attack of the previous summer. So far back as the summer of 1911 the improvement was manifest, as shown in the following report of the local branch of the Royal Arboricultural Society:—

"The larch plantations were found devastated by the saw-fly, but at Thirlmere they were green and vigorous. Here the Manchester Corporation have waged successful war against the swarming cater-

pillars by spraying and tar-banding the trees and erecting nesting-boxes for the birds."

We have then at least independent evidence that the only landowners of the district that adopted remedial measures did benefit to the extent of at least two years' growth of timber as compared to those who did not.

Our investigations on the activities of other agencies at work in the control of the larch saw-fly led to some interesting and important discoveries. In addition to the small birds that feed upon the saw-fly and its caterpillars in the summer, we found that the starlings, pheasants, and probably the rooks—as well as the field-mouse—destroy large numbers of the pupæ as they lie on the ground in the winter, but probably the most destructive agent is the ichneumon parasite *Mesoleius tenthredinis*. In the winter months we collected a large number of the pupæ and kept them in cages until the insects emerged, and we found that a certain number were always parasitized, the ichneumon emerging from the pupa instead of the saw-fly.

Thus in 1908 we found that 5.8 per cent of the pupæ that hatched were parasitized, 10.9 per cent in 1909, and 62 per cent in 1910. In 1911, however, the percentage fell to 18, in 1912 to 8, and was even less than that in 1913. But with the diminution in the percentage of pupæ parasitized by the Mesoleius, we found an increasing number were parasitized by two other insects, the Ichneumon *Hypamblis albopictus* and the Tachinid fly *Zenillia pexops*, and thus the war of insect upon insect never ceased to rage. The important part that is played by these parasites in keeping this pest in check cannot be overestimated.

It is probable that under normal conditions there are always some larch saw-flies in the larch plantations, but the number of those that survive the attacks of

their natural enemies is so small that the damage they do to the trees is inappreciable. It may be important, therefore, in case of any new outbreak of the pest, to note if the most important known parasites are present or absent, and in the latter case to supply the district with a number of specimens. That this transfer can be effected has recently been demonstrated in an interesting experiment.

When Dr. Gordon Hewitt left Manchester to take up his position as entomologist to the Dominion Government in Canada he found the same saw-fly causing great damage to the larch trees in Manitoba and elsewhere, but on examining the pupæ he did not find any specimens of the parasitic ichneumon (*Mesoleius tenthredinis*) referred to above. A large number of pupæ were therefore sent to him from Cumberland, and the ichneumons that emerged from them were liberated in the Canadian forest. It was possible, of course, that the severity of the Canadian winter and many of the other influences that regulate the balance of nature might prove unfavourable to the British immigrant, but Dr. Hewitt was able to report that in 1916[1] the ichneumon parasite had been recovered, and was therefore presumably already acclimatized. We have therefore been able to supply the Dominion with a valuable ally in its battle against the saw-fly, and we may confidently believe that in due time it will prove its value.

In these matters of economic entomology we seem to have reached only the threshold of knowledge. We have obtained some interesting and a few valuable results, but we really know nothing of importance about the vast struggle for existence that is going on in the insect world, not only in the open air during the summer months, but all through the winter in the

[1] Report of the Dominion Entomologist, 1917, p. 9.

dark recesses of the soil. If we take a cubic foot of the surface soil of a meadow and search it carefully bit by bit with a lens and a microscope, we find hundreds of larvæ and pupæ and adults of insects that feed upon the roots of the grasses or prey upon one another, and many of these have not yet even been named or described. Thus by this method Dr. Cameron found in a small field near Manchester 160 different species of insects in the soil, many of them being present in great numbers.[1] The play of forces in this mixed community, the struggles for food, the powers of reproduction, the death and destruction, is intensely involved. All that we know at present is that when we employ the method of injecting poisonous vapour into the ground to destroy a particular species of insect pest, we must also destroy hosts of other insects, some of which at least are our friends and benefactors. We are recklessly taking part in a warfare without knowing even the strength and disposition of the forces that are fighting on our side. We are striking out blindly, destroying friends and foes alike. Now it seems to me that this state of things should be amended. We should at least endeavour to extend our knowledge of the natural forces that are playing such an important part in the maintenance of the fertility of our own soil. But this work which should be done, which must be done if we are to have a really scientific basis for our agriculture, requires the services of properly trained entomologists. But of young entomologists we have but a few left in this country; some of them are fighting in the ranks, others are threatened with a summons to the colours, and others have been driven abroad or into the service of the colonies by the want of recognition at home. We

[1] A. E. Cameron: *J. Econom. Biol.*, VIII, 1913, and *Trans. Roy. Soc.*, Edinburgh, LII, 1917.

have, I believe, the best material in the world. We have the means of bringing it into use, but we do not employ it in the service of the country. If people only realized the enormous loss to the country involved by this neglect of science, I cannot help feeling that some steps would be taken to find a remedy. But we have no statistics, no reliable estimates, to put before the public. Professor Dean[1] recently estimated that, in the State of Kansas alone, the insect pests cause damage to the extent of 30 millions of dollars per annum, and other estimates by the American entomologists are given at 10 to 40 per cent of the crops, destroyed by insect pests.

Now if we take the wheat crop alone in this country, which is estimated at 10 million quarters—worth, at sixty shillings a quarter, £30,000,000—and reckon the loss by insect pests as 10 per cent, we see that the damage we are trying to prevent by saving all our food crops from the ravages of insects represents a matter of millions of pounds per annum. The war, with all the hardships and suffering it has produced, has taught us the national need of economy of our food-supplies. We may trust that it will also bring home to us the losses we have been content to suffer by our neglect in the past of the cultivation of applied science.

[1] Dean: *J. Econom. Entomology*, II, 1918.

S. J. H.

CO-OPERATION IN FOOD-SUPPLY

The general title of this course of lectures was framed to include a wide range of topics, but I am afraid that it is only by a stretch of language that my subject can be brought within its limits. The production of food-stuffs really depends on the exercise of certain arts—the arts of dealing with plants and animals so as to produce food from them—and, as in the case of all such arts, which are as old or nearly as old as human history, its practice is based upon the mass of acquired tradition which has been accumulated through countless generations, and which is still enormously more important in the actual practice of agriculture, horticulture, and stock-breeding than are the results of scientific research. In food production, i.e. in stock-raising, crop-growing, and so on, as in everything else, however, the results of scientific research are becoming more and more potent in actual practice with every year that passes. Then, again, the co-operative organization of food production and food supply, about which I am going to speak, demands a considerable knowledge of the psychology of various kinds of human beings, a practical and intimate acquaintance with human nature. Because the material dealt with in the production of food consists of living beings, and because the organization of the co-operative production of food means dealing

with human beings, my subject touches upon biology, but, of course, only indirectly. It is for this reason I say that it is only by a stretch of language it can be properly included in this course.

It is a commonplace with those who concern themselves with the history of what is called the co-operative movement in this country, that, while Co-operative Distribution has been a gigantic success, Co-operative Production, speaking generally, has been a comparative failure. By Co-operative Distribution is generally meant, in this connection, that gigantic system which has spread throughout the towns and cities of England under the control of the Co-operative Union. The size and importance of the Co-operative Union, with its familiar "stores" in every city, town, and large village, often acting as social and educational centres, are well known to us all. But with this side of co-operative trading we are not concerned to-day. Co-operative production of food-stuffs, on the other hand, has in England lagged behind the great advances made in other countries, and it is only within very recent years, as a result of the activity of the Agricultural Organization Society, that any substantial progress has been made. Even now we are far behind other countries in this respect.

It is often said that English farmers and English small-holders are too conservative, too suspicious of one another, to make it possible successfully to organize schemes of co-operation among them; but I do not see any evidence at all that they possess these qualities in any more marked degree than the farmers or small-holders of other countries. It is indeed true that people who live on the land have impressed upon them the same influences, whether they be Serbs, Rumanians, Irish peasants, American fruit growers, or English farmers, and the main result

of life on the land is seen in the common characteristics which are displayed by agriculturists all over the world. Their life of comparative isolation on the land and their very intimate contact with nature, the fact that they have successfully adapted themselves, on the basis of inherited tradition and the very slowly accumulated results of experience through the centuries, to the great yearly cycle of nature, with all the danger and uncertainty of seed-time and harvest, have an inevitable effect on the mind and character. It is these things that make them less anxious to try experiments and less susceptible to new ideas than is the case with townspeople, nor do they easily organize themselves in the common interest. But this applies, as I say, not specially to people living on this island, but to people living on the land everywhere.

Now the isolation, which is at present, at any rate, a pretty constant factor of life on the land in most countries, together with the slowness of mind which it engenders, brings about another result. It makes the agriculturist, particularly the small agriculturist, the easy prey of unscrupulous people of various kinds —money-lenders and vendors of things which the agriculturist needs, such as his agricultural implements, seeds, fertilizers, and so on. And that very fact has brought its own remedy, because it makes a suitable seed-bed in which can be planted the seed of a co-operative movement, and it is in this way that the development of co-operation amongst agriculturists has actually taken place.

The first important movement of the kind originated in Germany in the middle of last century. The German peasants and small farmers were in many places the prey of unscrupulous money-lenders, and the disease produced its remedy. The agriculturist is particularly in need of obtaining credit easily. The ordinary

trader can, if he has a business started, obtain credit on a security basis, because banks make a practice of advancing money in that way. But the ordinary bank does not generally understand the needs of the agriculturist, and will not lend money on any security the farmer has to offer. Nevertheless, the agriculturist needs the credit if he wants to enlarge his operations or to undertake any new work. He even needs it more than the ordinary trader, because, while the trader can start his turnover at once, the agriculturist has to wait while his seeds grow and his crops ripen until he can reap his harvest. And all that time, apart from rent, he has to pay for labour, for the feeding of his animals, and so on. This need of the agriculturist is seized upon by money-lenders in every country, and the necessity of the peasant or small farmer is their opportunity.

In Germany co-operative credit societies were started on the so-called Raiffeisen system, from the name of the man who suggested it. Essentially the system is that a community of people who know one another become jointly responsible for the repayment of loans to any one of their number. The security is simply the personal character of the borrower, his reputation for honesty, industry, sobriety, and so on. Although many people might hold up their hands in horror at the suggestion that any such system could be successful, it has worked exceedingly well, because no such society would ever grant a loan to a man unless they believed in him. An essential condition of such a society is that there should be personal knowledge of all its members, and therefore the unit must necessarily be small. These societies increased enormously in Germany from the middle of last century to the end, and a few years ago there were over 4000 of them, with a total loan account for the year of

4½ millions sterling. To prove that their operations really came home to the small man, one may mention that over three-quarters of these loans were for sums of £50 or less. The Raiffeisen type is an excellent example of a primitive but quite thorough kind of co-operative society. The thing is perfectly sound, because it is conducted on sound principles, and it meets the first great demand of the agriculturist—easy credit. The Raiffeisen system has undergone many developments in Germany. In 1910 there were more than 15,000 agricultural loan and savings banks of various kinds, associated with and partly financed by 36 central banks, the total turnover of which in 1909 was more than 245 millions sterling.

The example of Germany has been widely followed elsewhere, including most of the European countries. Outside Europe, the system, or rather a modification of the system, has been developed, largely on Government initiative, in India for just the same purpose. There it is run locally, but supervised by Government, and the members of the local societies accept unlimited liability quite freely. Part of the magnificent work of Sir Horace Plunkett in Ireland has been the formation of credit societies, and this has been a tremendous boon to the honest and industrious Irish agriculturist, whom it has rescued from the slavery of the money-lenders. In England there has as yet been little development in this direction, though there has been much talk recently about land banks.

The second great need of the agriculturist is to obtain at a fair price and of good quality the necessaries for carrying on his work, that is to say, agricultural machinery, implements of all kinds, seeds, fertilizers, and so on. Exactly the same kind of thing happened in Germany in this connection. The farmers found that they were rapidly coming under

the domination of syndicates of manufacturers of those things which they wanted, rings which kept up the price and then supplied inferior articles, and combinations of farmers on co-operative lines were made to meet this difficulty. It is clear that the farmer effects a great saving if he can buy from a society which purchases the best qualities wholesale, and charges only a small commission to cover expenses, instead of buying from a trader who seeks a profit only limited by competition, and not always by that. A few years ago there were twenty-seven great co-operative supply societies in Germany working on a very big scale, with a total membership of over 10,000, mainly consisting of small local affiliated societies up and down the country. Other countries have followed Germany's lead in this matter also, and successfully too, though generally with far less complete organization.

These two functions of which I have spoken, very necessary functions indeed for the welfare of the agriculturist, that is to say, the provision of credit and the provision of what may be called, in the broadest sense, agricultural plant, have often been associated, in the sense that one society will both buy for and sell to its members machinery, seeds, &c., and will also grant credit.

One may say that the two things of which I have been speaking are the simplest to organize on co-operative lines. But in addition, of course, we have the other side of the farmer's needs—the disposal of his produce. Here again is a vast field for co-operation in dealing with produce on its way from the land to the consumer. In this dispatch from the land to the consumer many different processes are involved, varying, of course, with different commodities, and in order to organize effectively co-operative dealing

with these processes each commodity and each of the different processes it has to pass through has to be gone into and studied separately. All that side of agricultural co-operation, therefore—what you may call generally co-operative marketing—becomes a very much more complicated problem than the supply of necessaries and of credit to the agriculturist, a problem which people have tried to solve here and there many times, and have very often failed. The easiest and least dangerous way to attack it is for a co-operative society to deal, in the first place, with a single article.

There are many examples of this, one excellent example being the Irish dairies, which have been established under the Irish Agricultural Organization Society by Sir Horace Plunkett and his fellow-workers. These co-operative creameries, in which butter is made from the farmers' milk and then distributed, have been such an extraordinary success that capitalists have imitated them and laid down creameries on exactly the same lines, and between the two this field in Ireland has been pretty completely covered for some years now. Nearly all the milk produced in Ireland, except that locally consumed, is turned into butter at creameries of this type. In England the conditions are different, and it pays the English dairy farmer much better to send his milk straight to the towns for direct consumption. Here, of course, there is still a field for co-operation in the collection and delivery of milk, but the marketing of milk is in an exceptional position because of its vital importance to the inhabitants of the towns. Because this matter is of such vital interest to the consumer there has been an important movement to bring it under the control of the municipal authorities or of the State, with a view to controlling the price and even to controlling both price and distribution. It must be remembered that a co-

operative society may indulge in "profiteering" as well as the private trader, and in the matter of the milk supply this is an actual danger which seems to have been realized, or is likely to be realized in the case of at least one powerful society operating in a large centre of population in this country. Such a danger is, of course, no objection to the principle of co-operation, but it is as well to remember that in the case of essential commodities like milk the interests of the urban consumer must override the financial advantage of the country-side. Even if the retail price is fixed, however, co-operative methods will still give the producer a better profit than selling to a middleman.

The type of marketing society which should be established in any district or locality depends, of course, on two factors, the actual production of the locality and the available markets. Outstanding examples of this are to be found in Denmark and Ireland. There the conditions of success are given by the fact that these are stock-raising countries, dairying countries, and pig-breeding countries, and by the proximity of the great British markets. Most of the bacon and butter of Denmark came, before the war, to England, and so does most of the Irish bacon and butter. The co-operative creameries of Ireland and the bacon factories of Denmark, as well as the co-operative stock-breeding societies which improve the strain of the animals from which these products are obtained, are all dependent on these factors.

A specialized society dealing with a single product has very great advantages. The business it has to do is less complicated than in the case of a society which deals with miscellaneous produce. It is therefore easier for the managers to obtain a thorough working knowledge of the conditions of production

and marketing, so that success is more likely. A local organization can cope with one commodity, but may not be equal to dealing with a wide range of produce, each kind of which, owing to the difference in the conditions of production, necessarily needs a separate organization.

As an example of specialized co-operative societies which have had literally gigantic success, one may mention the American fruit growers' associations. The enormous increase in the production of fruit along the Pacific slope and in some of the north-eastern States, such as Michigan, created a demand for further outlets. The peach and grape growers of California and the Oregon pear growers had to find markets not only in the great urban centres of the eastern States but also in other countries, and only a very powerful organization with great reserves of capital at its command could find out and study these markets and supply their needs cheaply and profitably. The fruit growers soon found that they were getting under the thumb of the middleman, and they combined to meet the danger. There are combinations of this kind in all the great fruit-growing States of America, and one of the most powerful and important of these is the California Fruit Growers' Exchange, with head-quarters at Los Angeles. Some years ago this association was dispatching to market 14½ million boxes of fruit annually, showing a gross profit of 4½ millions sterling. This association is really a federation, having its head-quarters at Los Angeles, and its governing council is elected by about fourteen principal district associations, which, in their turn, have connected with them more than a hundred local societies with an aggregate membership of 14,000 individual fruit growers. The exchange had agents in the United States, in Canada, in London, and in

certain other European capitals. These agents were in constant touch with the markets, and also in communication with Los Angeles. Thus market information was communicated as necessary to the districts, and the local societies took charge of the collection of fruit from the growers, and of the grading, packing, and bulking in complete truck-loads, which in due course were put in trains for their destinations. In this way the fruit growers received a higher price for their fruit, and at least 50 per cent of the expenses of marketing have been cut away.

That, of course, is an example of an organization on a very large scale, but there is no reason at all why smaller organizations of the same kind should not be started, and successfully started, in this country. Certainly there are some, but not many. The essential factors are a thorough study of market conditions, really good management, and insistence on first-rate quality. This last is a point of the utmost importance. I know a pear grower in Oregon who can practically fix his own price for dessert pears on the London market, 6000 miles away, and he only does that by absolutely refusing to pack anything but fruit that is quite perfect. In packing he rejects, without hesitation, fruit that most of us would call first rate. He will only include fruit without spot and of perfect form, and he dominates his market because his customers can absolutely rely on receiving nothing but perfect fruit. In this country it is most necessary that the small fruit grower's standard should be constantly raised. At present he is extraordinarily slack about quality, and expects to sell fruit which is often very inferior. Particularly he does not understand what is called grading—that is to say, the sorting out of fruit into different sizes and qualities, and then putting each on its proper market. The value of every kind

of fruit is greatly increased by proper grading. At Covent Garden, for instance, the fruit dealer, when he is supplied with a mixed sample, invariably prices it at the price of the worst quality of fruit included, so that the producer loses the difference between that price and the average price of the grades into which the sample ought to have been sorted.

I have already pointed out the obvious fact that in the transit from the land to the consumer most agricultural and horticultural produce has to go through many processes, and that these necessarily differ for each commodity. Thus while milk could be sent direct from the cow to the retail shop, pigs have to be turned into bacon, wheat into flour, and so on. These preliminary processes are, of course, quite distinct from marketing, and many of them can be dealt with co-operatively. For instance, as we have already noted, bacon factories and creameries have been among the most successful of co-operative undertakings. You have to separate your milk for making butter and kill your pig and make bacon of him before your produce is marketable. This, of course, is specialized work, and it is advanced work in the sense that only a community which has seized the principle of co-operation and is prepared to work upon it can possibly undertake it with success. Most untutored agricultural populations want a very great deal of education in co-operative methods before they can successfully carry out schemes of this sort.

When we come to deal with fruit and vegetables it is obvious that the number of processes between the land and the consumer are much fewer. You can pick fruit and pack it and send it to the private consumer direct if you like, and similarly with vegetables of various kinds. But even with fruit, when it is sold wholesale, there are processes which have to be gone

through, such as grading and bulking for transport, and these can be done co-operatively, and form one of the simplest and most hopeful fields for a new co-operative society to take up. I have already referred to the importance of grading and to the way in which it raises the value of a crop. Bulking for transport is another important function of a co-operative society. As you know, railway companies quote lower rates for large quantities, the usual unit being a truck-load, and one of the great advantages of a co-operative society is that the produce of a number of members can be collected, graded, packed and bulked so as to make up complete truck-loads.

Then we come to the actual marketing of the produce. First of all we have to consider the accessibility of markets and the kind of market that is to be sought. There is often a choice of markets, some of which offer one advantage and some another. Then we have to consider whether we are going to dispose of our produce to a wholesaler or to a retailer, or, as is possible in some cases, direct to a private consumer. Then there is the whole question of transport, on which I have touched: this is largely concerned with rates and bulk. It must never be forgotten in this connection that the middleman who buys from the farmer and sells to the wholesaler or retailer, exorbitant and oppressive though he may occasionally be, discharges an important and indispensable function. In most cases he gives good value for the commission or profit he takes. He knows the goods in which he deals, and he knows his markets and transports. If he had not a good knowledge of these things he could not be successful. In nearly all cases an officer of a co-operative society can undertake this work and thus save the middleman's profit to the producer, but if the society is going to per-

form the functions of the middleman it must acquire, through its officers, the same knowledge as the good middleman has. From all these considerations it will be clear that co-operative dealing with produce (co-operative production in the widest sense) is a very complicated problem which can be mastered only by a close and careful study of the conditions involved. Success can be achieved only by knowledge and by careful adaptation of means to an end.

There have been many attempts to organize the supply of our home country produce, and many failures through not recognizing the proper starting-points or from omitting to attend to some factor essential to success. One rather instructive case is that of an organization called the British Produce Supply Association, which was started in 1896 by Lord Winchilsea and other influential people under the auspices of the National Agricultural Union. The British Produce Supply Association was started experimentally as a limited liability company with a capital of £50,000. The idea was to have first of all a distributing centre in London from which produce could be obtained by the retail trade and by private customers, and depots in the country, in charge of agents who would guarantee farmers a better price than they would get locally, would collect produce, grade and bulk it, and dispatch it to London. It was thought that this offering of better prices would incite agriculturists to produce better quality, and, if they could not, it was thought that the agents of the association would act somewhat in the capacity of technical instructors by teaching and explaining methods, by distributing leaflets, and so on. Operations were actually started at Sleaford, in Lincolnshire, with a distributing head-quarters in Long Acre.

But things did not happen quite as the promoters

had hoped. There were many difficulties and causes of failure. One of these was that the producers continued to sell their first-class produce to established dealers, and expected the association to take second-class produce and give good prices, their notion being that, as the association was started for the benefit of the agriculturist, it ought to pay good prices for whatever they chose to offer. They felt hurt when their supplies were rejected, and still more so when the local agent started on his educational work of teaching them what they ought to do. That attitude is extremely common among agriculturists, particularly small ones, and it points, I think, directly to an essential condition of successful co-operation: that you cannot start co-operation by making the organization independently of the actual producer and then asking him to come into it. You must start with your operations based on the desire of the producer to make his business more profitable; you must secure his interest in the first place. He must put his own time, energy, produce, and money into it, and must elect his own officers. The organization started from outside, however enthusiastic its promoters may be to increase the produce of the country, is not likely to be successful; it is not the right way to begin. This does not mean that there is no room for propaganda and for people who are enthusiastic to bring before the actual producer the advantages of co-operation, to tell him the history of experiments, to suggest the right methods of organization, and so on. There is much room for propaganda and educational work; but, so far as I know, there has not been a really successful association started except at the desire of the producers themselves, actuated by their own wish to dispose of their produce to the greatest advantage. That is the bed-rock on which co-

operative producing societies must be based, and no amount of enthusiasm or devoted voluntary work can replace this primary interest of the actual producers.

The necessity of these various conditions of successful co-operation is clearly seen in the case ot societies of this kind which are springing up all over the country as a result of the food situation which has developed so rapidly during the last year. Many of them are run too much from outside, and do not start from the producer. Many of them try to do too much and to deal with too many things. One of them, with which I have a close acquaintance, covers very nearly the whole range of different functions which I mentioned as belonging to the different fields of co-operation, that is to say, it provides implements, seeds, fertilizers, food for live stock, and it also undertakes to market produce. There are a good many societies in this country trying to do too much with too small resources. It is very much better to follow on the lines which the history of the subject has marked out, and to start, if possible, in a small way, with a single commodity or a restricted group of commodities, to specialize, to induce your producers to try the co-operative methods of dealing with their produce, to pay special attention to grading and to the maintaining of a uniform quality, to keeping your market when you have got it; and then, when you obtain success on a limited scale, build on that and do not launch out much further than you can see.

This is an important point at the present moment, for war conditions are abnormal and difficult. While they supply a great stream of voluntary enthusiastic work, this is temporary, and though, at the time, war conditions necessarily supersede normal conditions, and stress is being laid upon increase of quan-

tity to the neglect of quality, such a state of affairs cannot be permanent. Consequently, any temporary success or failure now is very little guide as to whether you are going to meet with permanent success or failure. Dealing with surpluses without regard to quality is, on the whole, a problem better left to State action. But if, *under the stimulus of war conditions*, it is possible to lay on sound lines the foundations of a local co-operative society which would not otherwise be started, that is a worthy and admirable goal to which local effort may be directed.

The principle of co-operative dealing is absolutely sound economically, and its financial advantages are probably its most striking feature. But co-operation has a further advantage which the financially successful great joint-stock companies cannot lay claim to, and that is this: co-operation once started among producers for the protection and furthering of their interests not only preserves the individual pride of the producer in his own produce, but leads to the replacing of suspicion by confidence and of isolation by ideals of mutual help. This has actually been shown most undoubtedly in the case of Ireland to be the effect which follows in the wake of successful co-operation. Not only have good crops been produced where there were bad crops before, and prosperous cottages built in place of hovels, but the intellectual and moral life of the community has enormously improved in many ways. The introduction of a co-operative society has, in fact, resulted not only in bringing more money to the community, but in increasing its social activities and generally has tended to re-create rural life. The evidence of this in different parts of Ireland is so widespread and striking that it cannot be ignored. English rural life has never been in such a bad condition as that of Ireland was thirty or

forty years ago, but I think most of us will agree that a good deal of improvement is possible, and what has been done in Ireland can perfectly well be done in England if we go the right way about it. Co-operative effort directed wisely and with a real appreciation of the essential conditions of success is therefore one of the most useful and productive ways in which we can help forward that reconstruction of the life of the nation on better lines, which we all hope to see as a result of the times of stress and suffering through which we are now passing.

A. G. T.

THE PHYSIOLOGICAL ASPECTS OF FLYING[1]

Owing to the exigencies of modern warfare, a youth about eighteen years of age may be called upon in the course of a comparatively short time to acquire a mechanical knowledge of an aeroplane and how to handle it; and then, in yet a few weeks more, may be flying at a height of $3\frac{1}{2}$ to 4 miles on photographic reconnaissance over hostile territory, or engaged in aerial combat over the enemy's lines.

It is hardly an exaggeration to say that such a lad is probably subjected in that short period of time to a greater strain than were his forbears over the many thousands of years of evolution.

As a result of war conditions, there has been a substantial increase in the speed of aeroplanes and the heights to which they can attain. Despite improvements in aeroplane construction, and the increased reliability of engines, the nervous excitement and strain brought about by war flying have become greater. It is now necessary, not only to fly a machine, but in many cases to be able to "stunt" it in a most extraordinary and nerve-trying manner. Aerial combats have increased, the aim of anti-aircraft guns has improved, and new tactics, such as "ground strafing", have been introduced.

[1] Owing to the requirements of the censor, certain facts and figures given in this lecture have been omitted; other passages have been amplified, and additional information inserted.

For the observer the scope of activities has also become very much greater.

In addition to such nervous excitement, the increased height to which machines fly has imposed a great physical strain, especially upon the mechanisms of respiration and circulation—all this in addition to the physical and nervous stress encountered during the period of training. In short, in a relatively brief space of time the young pilot is called upon to break the ancient bonds by which man's progress was tied to the earth, and to rise from ground-level to great altitudes, from comparative warmth to intense cold, from relative quiet to continuous rush and roar, from a state of equilibrium to one of instability, from muscular and mental rest to highly skilled and nerve-trying evolutions, from comparative security to possible disaster, all this in a space of relatively a few minutes—with a return to earth at least as sudden—thereby subjecting himself to intensive, intermittent, and cumulative stimuli of a degree to which man has probably never before been exposed. It is obvious, therefore, that for such work the aviator must be the fittest of the fit.

From the historical point of view the literature in regard to early aeronautics and to life at high altitudes affords valuable information concerning certain of the present-day physiological aspects of flying. In other respects, however, it will be seen later that such information is of little value.

In regard to the effect of altitude, the essential problem is that dealing with the diminishing amount of oxygen in the atmosphere. It has long been known that with 17 per cent of oxygen, although a match will not burn, a man feels little or no discomfort. With 14 per cent the depth of breathing is augmented, the blood pressure slightly raised, and the pulse rate

increased. With 12 to 10 per cent of oxygen in the atmosphere, nervous "exaltation" appears, approaching in many cases almost to an intoxication, so that the subject has the greatest confidence in himself, although in reality his mental capacity is greatly affected. This "exaltation" varies in degree with different subjects, and has been studied by experiments in chambers from which the air has been gradually pumped out, by such tests as getting the subject to add up figures, to score out n's and r's in proofs, to bisect lines of definite length. For example, the writer, while testing oxygen apparatus in a rarefaction chamber, has frequently experienced considerable difficulty in reading correctly the meter at diminished pressures approximating to 18,000 feet. With a pressure equivalent to 22,000 feet, when not breathing oxygen, it has been subsequently discovered that all the notes made were practically illegible, and the writer at this time has been very uncomfortable and giddy. In contrast, an old seaman, R.N., was able to assist in the manipulation of the apparatus without apparently showing signs of incapacity or distress.

Finally, with very small percentages of oxygen there may supervene, without warning, paralysis, and, possibly, death. In the famous balloon ascent of Coxwell and Glaisher to 29,000 feet, Coxwell, suddenly finding himself paralysed in his limbs, managed to pull the rope of the safety-valve with his teeth, thereby saving himself and his companion.

In another famous balloon ascent the aeronauts, Crocé-Spinelli, Sivel, and Tissandiér, were all paralysed before they could breathe oxygen from the bags with which they had provided themselves, although they had been warned by the famous French physi-

ologist, Paul Bert, not to wait until too great a height was attained before taking oxygen.

It may be pointed out in passing that such accidents are not possible at the heights at present attained by aeroplanes.

Mountain sickness is characterized in most subjects by headaches, nausea, and distress in breathing, especially on exertion. After a period of seven to ten days acclimatization takes place, mainly due to a new formation of hæmoglobin, the oxygen-carrying pigment of the blood, or to an increased number of red blood corpuscles. Also, after the first few hours, an attempt at acclimatization is made, in so far as the blood is concentrated by a diminution in the amount of its watery portion, the plasma, so that its oxygen-carrying capacity is thereby relatively increased.

In flying, even in a first flight, provided no alarming evolutions are indulged in, there is at first little or no sensation beyond the sheer enjoyment experienced in rising higher and higher above the fast-receding earth. The depth of respiration is gradually but imperceptibly increased, until, at a height of 12,000 to 15,000 feet, almost everybody breathes through the mouth as well as through the nose. Following the deepening of respiration there is a quickening of the pulse, and, as the height is increased, a rise in the blood pressure. When a great altitude is reached, there appear, varying in different subjects at heights from 15,000 to 21,000 feet, muscular weakness and subjective and objective nervous sensations. Less often there is nausea and occasionally vomiting.

Before the use of oxygen at high altitudes it was not an uncommon occurrence for an airman who went to photograph at altitudes of 20,000 feet or more to believe from the results attained that his camera had

been at fault. In reality the camera had been in good working order, and it was he who, owing to muscular weakness, could not pull the shutter, or, owing to his cerebral condition, forgot to change his plates. In some cases hallucinations occur at such high altitudes, e.g. the reporting of phantom hostile air-craft flying at quite impossible heights.

Since, however, the length of even long flights is of relatively short duration, there is but little opportunity for any acclimatization of the body to high altitudes. No airman can yet take the air and remain at a height of 15,000 to 20,000 feet for the seven to ten days necessary to give him any permanent degree of acclimatization.

Supposing a man is a high flier, and has been in the air for 1000 hours in the course of 1½ to 2 years, it is probable that the time he has spent above 15,000 feet is 240 hours (or 10 days) at the most in that period. In other words, his total stay at a high altitude has been so short and so intermittent that there has been no time for any acclimatization to take place. It is this which complicates the subject of flying stress, and renders the information obtainable from previous literature of but little service, thus necessitating the tackling of the problem afresh.

It must be emphasized that in regard to the so-called illnesses associated with flying, one is not dealing with any definite malady, such as divers' palsy or caisson disease, for disabilities resulting from flying are due almost solely to the wear and tear on the organism as a result of repeated intermittent strain upon the bodily mechanisms. The condition of fatigue which ensues as the result of flying may arise equally from other forms of stress, such as severe and prolonged exposure in the trenches.

Considerable misconception prevails as to the effects

of diminished pressure on the human body. It was shown by Paul Bert, and has been subsequently confirmed by other observers, that diminution of atmospheric pressure has in itself practically no effect upon the human body—which is composed of approximately 70 per cent fluid—any alteration in external pressure being transmitted equally to all parts of the body, so that no effects due to pressure arise within it.

The diminution in pressure experienced by aviators is quite insufficient to produce gaseous emboli within the circulatory system, and therefore there is no question of any "air disease" akin to divers' palsy.

The only pressure effects which take place are those due to alteration in the volume of gas occluded in spaces which, although apparently within the body, are in reality situated outside it. For example, there will be a certain effect upon the gases within the alimentary tract, but insomuch as the amount of this gas is not normally large, and its expansion produces increased intestinal movement, such gas is soon voided from the body.

More important, however, from the point of view of the aviator, is the air normally occluded within the passages leading from the back of the pharynx to the tympanic membrane of the middle ear, namely, within the Eustachian tubes. Since the passage leading to this membrane by the external ear is wide and the passage of the Eustachian tube is very narrow, and normally more or less closed, and since also it is important that the pressure on both sides of the tympanic membrane shall always be the same, it is very necessary that the equalizing of pressure by way of the Eustachian tubes shall be easily accomplished, otherwise discomfort, pain, and giddiness may arise. Especially is this the case when the pressure is increased through the external ear and not equalized

by way of the Eustachian tubes. For this reason the Eustachian tubes of every aviator should be clear and uncongested. This applies equally to both tubes, for, if one be free and the other blocked, dangerous symptoms due to changes of pressure may arise. It is important, therefore, that every flying officer shall be taught the correct procedure by which to equalize the pressure on either side of the tympanic membrane both during ascent and during descent.

During ascent the pressure through the Eustachian tubes may be diminished by forcibly swallowing, when a clicking should be heard in both ears, or, better still, by the first stages of a yawning movement.

During descent, particularly if very sudden, the pressure within the Eustachian tubes may be increased by holding the nose and gently insufflating by a blowing-up movement, when a clicking should be heard in both ears.

A certain degree of discomfort may also arise as a result of alterations in pressure upon the air contained in cavities associated with the upper part of the nose, such as the frontal sinuses. If the passages connecting these with the nose be congested, pain and discomfort may be experienced in the region of the lower forehead.

With these exceptions the effects of altitude are due to diminished oxygen tension and not to pressure, and it is obvious that the first thing required in any flier is that he shall be able to withstand the strain of frequently-repeated exposure to an atmosphere in which the oxygen is progressively diminishing as the height increases. Especial attention, therefore, is devoted to this point in the selection of the flying officer. By ordinary clinical examination it is determined that his lungs are sound and healthy, and an

idea of the power of a candidate to withstand the strain of altitude is obtained by directing him to hold his breath for as long as possible. It has been shown that the longer the breath can be held the higher, generally speaking, one can go without discomfort. The subject breathes out deeply to get rid of the expired gases, and then fills the chest well and holds the breath with the nose clipped. During the time that the breath is being held the oxygen is gradually being taken from the lungs, and the subject is exposing himself to a gradually rarefying atmosphere. Although expired gases are accumulating during this time, research has shown that the point of breakdown is due to discomfort arising from lack of oxygen, and it has also been shown that the longer the breath is held the lower, generally speaking, is the tension of oxygen reached within the lungs.

It has been shown by careful correlation with more complicated tests, such as the analysis of the lung gases before and after holding the breath, that the airman who can fly at high altitudes can hold the breath a relatively long time (eighty to ninety seconds), and does not experience discomfort until the oxygen tension within the lungs is relatively low (about 10 per cent), whereas the subject who always feels discomfort, even at relatively low altitudes, can hold the breath but a short time, and experiences discomfort even with a relatively good supply of oxygen remaining in the lungs (e.g. 14 to 13 per cent). The standards of this test have been set by the examination of successful pilots, and at the entrance examination the capacity of the subject to fly high is estimated by the length of time the breath is held, and also by the nature of the sensations experienced during the holding of the breath.

Valuable confirmatory information may also be

obtained by asking the subject to hold the breath in a similar manner after graduated exercise. By means of the exercise the heart beat is increased in rate, as it is at high altitudes, and from the length of time the breath is held, and from the sensations experienced, an even better idea can be gathered as to the endurance power of the subject at high altitudes.

By examination of successful aviators it has also been shown that the vital capacity — that is, the amount of air which can be taken into the lungs after the fullest expiration and fullest possible inspiration, should be sufficiently large. To test this, a special modification of an ordinary gas-meter may be employed. After having filled the lungs in the manner mentioned above, the subject is asked to expire as deeply as possible through the meter, and the amount of the respiratory capacity is thereby automatically recorded. The average vital capacity of the successful pilot is about 4000 cubic centimetres, and the vital capacity of any flying officer should preferably not fall below 3400 cubic centimetres, whatever his physique.

This method of measuring the lung capacity is altogether more satisfactory than that of measuring the chest, which may give totally deceptive results. An apparently narrow-chested individual may often have a larger vital capacity than a subject who, to all appearances, has a large chest.

It is important that the candidate for aviation should have good chest movement, and a firm abdominal wall. Preferably also he should be a deep breather. By slow, deep breathing more air is taken in to the lungs than by more rapid, shallow breathing.

The importance of a firm abdominal wall for good respiration cannot be overstated. Research in connection with successful pilots has shown that those

who wear well have good expiratory force. From the examination of successful pilots a standard expiratory force has been fixed, namely, the height to which a column of mercury can be blown. When flying stress is supervening the power to blow up a column of mercury is decreased.

A variant of this test is to note the length of time during which a definite pressure of mercury can be sustained with the breath held. If necessary, the behaviour of the pulse may also be watched, and, from the nature of the response, valuable information is obtained as to the condition of the subject under examination.

Soundness of heart is as essential as soundness of wind. Over and above evidence of soundness by the ordinary clinical examination, proof is obained that it will respond efficiently to work. In flying, the heart will have increased work thrown upon it, sometimes in a much rarefied atmosphere, and the quicker the heart beats, even at ground-level, the more oxygen it requires.

Under stress of work at ground-level the heart-beat rises frequently to 100, but at great heights the rate is often considerably more than this, which means that under these circumstances an increased oxygen supply is necessary, with a lessened supply available. For this reason alone it is very important that the heart should be sound.

At the entrance examination for pilots for the Air Force, therefore, a test is employed which has been standardized by the examination of successful pilots. This consists in raising the body on to a chair five times in fifteen seconds. The standard increase of pulse rate which takes place in good pilots is known, and the time of the return to normal is also known, and, from the figures obtained, an idea as to whether

in the subject under examination these are satisfactory or not can be assessed.

It has also been found that in good pilots the pressure maintained within the circulatory system between the beats of the heart (known as the diastolic pressure) is relatively high, and that the difference between this pressure and the pressure when the heart is beating (the systolic pressure) is not more than 30 to 40 millimetres of mercury. The difference between these pressures should not be too great, and the diastolic pressure should certainly not be low in any subject passed for aviation.

It will be seen that in the examination of the candidate considerable reliance is placed upon instrumental examination. Such examination gives definite results, which can be recorded so that another medical officer at a subsequent stage in the career of the candidate can contrast the condition of the subject then found with that found previously. In this way the medical officer of an aerodrome is able to overhaul the human engines under his charge, and to say whether they are functioning well, wearing well, or showing signs of stress, and, if the last, to take appropriate measures to prevent it. For this reason, all such tests should be of the simplest possible nature.

In addition to wearing well, that is, in addition to being sound in wind and heart, other qualities are necessary for the pilot to become a successful aviator. Most important of all, he should possess the flying temperament. This, however, is very difficult to assess from a medical point of view.

Generally speaking, one prefers a man possessing what may be termed the "sporting temperament". The successful flier is practically always a sportsman. He generally takes up flying because he looks upon it as a sport. His previous record in games is in-

variably good. Often there may be a history of some accident or accidents probably due to the enthusiasm and recklessness with which he has pursued his sport. For example, enquiry has shown that a history of concussion in itself is not, as was once believed, a bar to acceptance for flying. As many as 40 per cent of successful pilots examined gave a history of concussion or unconsciousness. Such concussion is frequently associated with a degree of reckless enthusiasm so advantageous in the flying officer. There can be no doubt that the youth who, greatly exceeding the speed limit on his motor cycle, dashes into some obstruction and "flies" over it, is the possessor of the correct temperament to make a successful flying officer. Therefore, a history of concussion in itself is no bar to admission for flying, provided that at the time of examination there are no signs of nervous instability. Rather it is in his favour, since it shows that he is possessed of a nervous system capable of recovering from a certain amount of shock.

Considerable divergence of opinion exists as to whether the emotional or unemotional subject is likely to make the better flier. The French authorities pay considerable attention to so-called "emotional reactions", and by such means select their fighting aviators. For example, by the firing of an unexpected pistol shot the effect upon the respiratory and circulatory mechanisms is determined. This form of examination has not received so much attention in this country, but the so-called "emotive" test recently described by Dr. A. D. Waller, F.R.S., might be helpful in arriving at an assessment of the flying temperament. If, by means of electrodes applied to the dorsum and palm of the hand, a subject be connected in series with Leclanché cells and a galvanometer, an emotive response is shown by the latter, not only to physical

stimuli such as burning, unexpected noise, or smell, but also to psychical stimuli, such as apprehension, questions, and thoughts, pleasant and unpleasant. From many experiments made on various individuals it has been found that there is a marked difference in emotive response, and it would be of interest to know the nature of the response given by the examination of a series of experienced and successful pilots.

The successful sportsman possesses not only soundness of heart and wind but also valuable reflexes connected with delicate muscular co-ordination, acuity of vision and hearing, all necessary attributes in a successful flying officer. The capable horseman is likely to possess the correct lightness of hand to control in delicate fashion the joystick of the aeroplane. He has probably also acquired, by cutaneous and muscle sense, especially from the buttocks, a lively apprehension of the position of his body in relation to his seat.

The question of balance is, however, a rather difficult one. In Allied countries much attention has been directed to the examination of the labyrinthine mechanism of the internal ear. This mechanism consists mainly of three pairs of semicircular canals filled with fluid; the sensations from these yield information as to the position of the head in regard to the three planes of space. Although practised in this country, such detailed examination has not had so great a vogue, since it is realized that the impulses from the labyrinth must always be associated in flying with the sense of vision. By vestibular impulses alone the aviator cannot tell the position of his machine in regard to the earth, and is likely to emerge from a thick cloud upside down. Generally speaking, the airman derives most of his knowledge in regard to

the position of his machine in space from his sense of vision, the feel of his joystick, the feel of his seat, from the direction of the rush of the wind upon his face and the singing of the wind through the wires of his machine.

A medical man who went up as a passenger in an aeroplane, with his eyes bandaged and his ears plugged so that he could not hear the varying notes of the engine and thereby gather information as to what was taking place, was unable after the first few minutes to inform his pilot by telephone, with any degree of accuracy, the position of the aeroplane. In fact, he experienced the sensation that he was constantly rising.

This fact was also brought out to the writer in the following manner: greatly occupied by an instrument in the bottom of the fuselage, he suddenly cast his glance out of the aeroplane and received the impression that he was looking at the side of an enormous mountain. He quickly, however, appreciated the fact that, in reality, the apparent mountain was the flat earth below, and that he was in the middle of a steep vertical turn without being aware of it.

Good eyesight is of extreme importance for the airman in all branches of his work. In particular is this so for the scouting pilot, and it is a point of interest that it has been found that nearly all scouting pilots are possessed of such acuity of vision; it will be of interest to determine how much of this was acquired before flying scout machines, how much as a result of the training necessary to fly and fight in such machines.

Good colour vision is also necessary for recognizing signals, identifying troops, and judging the nature of landing-grounds. Good night vision is requisite for all pilots who fly by night, and it is now recognized

that this acuity of vision is considerably greater in some persons than others. Tests for this power of vision are accordingly being made.

Good hearing is also of importance, not only for ordinary apparatus such as the telephone, but also because a pilot should be able to judge to a certain extent whether his engine is running well or not; as already mentioned, he derives information from the singing of the wind through the wires. For many pilots, however, it is perhaps as well for them not to have too keen an appreciation of the running of an engine by its note, but only whether it is running really well or really badly.

Finally, in addition to good vision, hearing, and sense of touch, it is important that the aviator should possess good "reaction times", which is to say that he should translate the impulses received from the above-named senses into the appropriate necessary actions in at least normal average time, and, in the case of the scouting pilot, in times less than normal.

The importance of such reactions is seen in all stunting, since, with the aid of these senses, the aviator, by appropriate movement of the joystick, must complete his evolution, and any delayed response may result in difficulties—or even in disaster.

Such, in brief review, are the main physiological aspects of flying. The manner in which such knowledge is applied to the efficient care of the airman cannot be dealt with here. Suffice it to say that the keynote of such care is preventive, and, since physiology is the servant of medicine, much use is made of the methods here reviewed in determining the nature of any disability which may develop. By more elaborate methods disability at high altitudes may be investigated and its true nature sought.

The care of the flying officer is a great privilege.

No trouble can be too great, no care too skilful, no research too laborious in the endeavour to preserve and defend these youthful knights of the air, who, in defence of home and country, with gladsome and buoyant heart, on their new-found steed, soar daily forth "per ardua ad astra".

M. F.

THE ANÆROBIC TREATMENT OF WOUNDS

A layman, if he has to address a purely medical audience on a medical subject, labours under an obvious handicap, and I have been glad, therefore, to avail myself of the opportunity of these lectures to lay out for wider reception the matter of some investigations carried out at Reading War Hospital, which will, I think, have at least a topical interest for most people.

While the war has closed many avenues of advancement, and academic studies languish, it has opened many other roads which might have remained untrodden for long enough, and has proved an enormous stimulus to certain aspects of knowledge. Naturally this is the case in a superlative degree with medicine. War conditions and war needs in surgery are almost entirely foreign to civilian practice, especially in regard to the extensive nature of the injuries, their gross infection, and the chance which sepsis often gets of laying hold of the patient's system before thorough treatment becomes possible. To face such circumstances the civilian surgeon comes *qualis ab incepto.* He has to learn his job anew, and out of that fiery trial of strength, in which all accepted methods have been put to fighting proof, it is not surprising that things novel and unexpected should come to light.

Two schools of wound treatment have hitherto

divided opinion between them. The first is the antiseptic school, of Listerian tradition, the other is the "physiological" school of Sir Almroth Wright. Of both ideas there are many current modifications which do not need to be entered upon in detail here, except in so far as they directly concern our present subject. It will suffice to say that under both headings there are two main sub-divisions, those of irrigation methods and of packing methods. Treatment by antiseptics, however applied, has behind it the weight of long experience, but nevertheless it breaks down in the greater majority of cases when confronted with the *deeply established* infections of war wounds. The practical experience of surgeons in France and elsewhere has shown that antiseptics can only be relied upon in conjunction with surgical excision of the damaged tissues, a procedure which is at once more mutilating and more dangerous than anyone would wish. Moreover, in very deep wounds, or if important organs are involved, excision may be anatomically impossible; and even in the best of cases, if no freshly-lit infection of the new surfaces takes place, the procedure is cumbersome, and convalescence is more or less delayed; in the most severe cases very much more than less.

If excision be admitted as a practice, then "Carrel-Dakin" irrigation with hypochlorous acid, or packing with B.I.P.P. (the bismuth-iodoform-paraffin paste of Morison) may, with reservations, produce a satisfactory final result; but the reservations are very considerable, and it is safe to say that no antiseptic exists which is truly non-irritant *and* efficacious in such a degree as to diminish them.

Wright's method depends upon simple irrigation with hypertonic saline, without the application of any antiseptic. The basis of this practice is the belief

that the saline produces an exosmosis of serous lymph from the tissues, bathing the injured surfaces with protective substances and chemotactically attracting leucocytes in such numbers as to overwhelm invading organisms. There is no doubt that this marks a great advance on the antiseptic methods, and, without necessarily accepting the physiological explanations given of its action, one may admit its relative efficacy. Nevertheless it has, in common with antiseptic methods, two serious drawbacks which invalidate it for war surgery. One is its cumbrous application, which excludes it from field operations, and the other is the slow progress of recovery in extensive sepsis.

To overcome these difficulties Colonel H. M. W. Gray devised his method of packing with solid salt, a method which perpetuates the merits of Wright's treatment without its disadvantages, while the wound follows more or less closely the same course of changes which Wright lays down as essential to proper healing. Presenting such obvious advantages, this method has enjoyed wide popularity, and the results have been usually excellent. Even where old-standing infections, with dirty, sloughy wounds, have to be treated, with the patient frequently running a high temperature and in great pain, the minimum of operative interference is called for. After the introduction of the packs the patient can be left for seven to nine days without redressing, a great gain in rest and mental quietude for him, to say nothing of the surgeon. By the third day the temperature begins to come down, the patient feels comfortable, and the pain abates, even in most obstinate cases. When the packs are removed, the wound is found to be bathed in yellow pus, and the sloughs have been reduced at least to thin flakes which can be detached by

simple washing with warm saline. The surfaces are found to be covered by vigorous granulation tissue. The wound may be sutured or skin-grafted, and healing is uninterrupted.

This is the course of successful salt-pack treatment. By all the theories of the physiological school the lymphagogue and leucocyte stimulation by the action of the salt should result in the subjugation of the bacterial flora infecting the lesion, but numerical analysis of the flora, at all stages of the treatment, reveals undiminished numbers of organisms up to the time of removal of the packs. There is evidently more in the treatment than meets the eye; but yet no theoretical explanation of these observed facts has been forthcoming.

One of the most clearly apprehended points in salt-bag treatment is the terrible odour, which is accompanied by blackening of the injured tissue, scaring the old-fashioned surgeon with visions of gangrene. Far from that—it is the signal that all is going well. Major Leonard Joyce, of Reading, was the first to observe that stench and cure go hand in hand. No smell, no blackening; no blackening, no cure. Here lay the key to the puzzle. Following his observation, the matter was investigated bacteriologically under the inspiration and direction of Dr. Robert Donaldson,[1] the bacteriological specialist, and it was found in the laboratory that from the pus of successful cases a large oval-spored anærobe of a strongly proteoclastic nature could invariably be isolated, while it was just as invariably absent from the unsuccessful cases, which did not smell. This was christened "the Reading bacillus". It remained to determine the relationship of the bacillus to the treat-

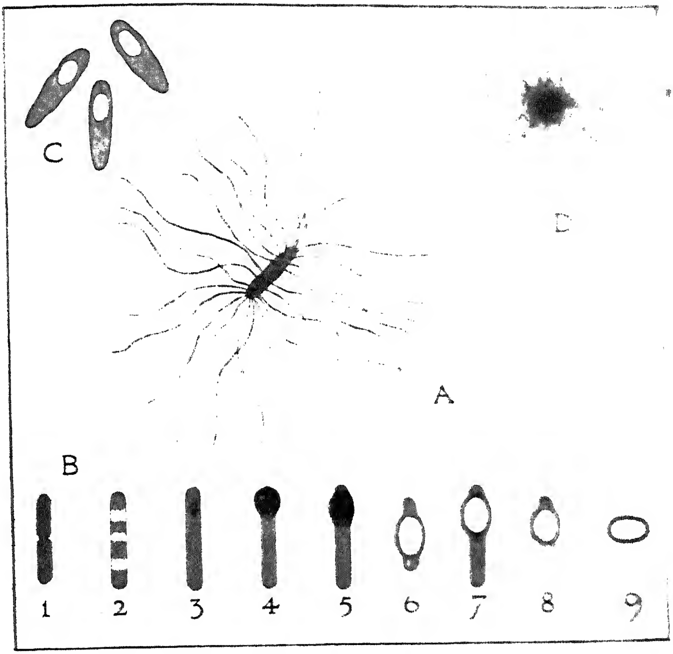
[1] See the preliminary account by Dr. Donaldson and Major Joyce in *The Lancet* of 22nd September, 1917.

ment. The organism is a strict anærobe, but, like most of its kind, it will grow without anærobic precautions in broth containing meat, after the method of Tarozzi. This in itself is significant if compared with the conditions in a wound. Such meat broth, made from the recipe of Miss Robertson, is an extremely valuable medium for anærobic cultures. In this medium, if it be sown with passive spores of the organism and incubated at 37° C., there is little change until *the third day*, when blackening and solution of the meat begin, and an odour develops which is unmistakably that of the salt-pack-treated wound. Notice, by the way, the correspondence between the period of germination in the meat broth and the time taken for the odour to develop in the wound—in both it is two to three days. Experiments on animals showed that the bacillus, now isolated in pure culture by a method of dilution, from single organisms, was non-pathogenic and non-toxic, however inoculated, and that it had no power to invade the blood stream or to attack living blood or tissues.

It is impossible to overlook the bearing of these observations upon the action of salt-packs, and as it was thought that the packing and the outflow of serum which results might provide anærobic conditions specially favourable to the organism, it was determined to introduce it, in pure culture, into a salt-packed case which had failed to improve, and which, therefore, did not smell. No risk was involved in this, as it was constantly present in just those very cases which did best. The first time a case of unsuccessful salt-packing presented itself it was decided by Dr. Donaldson to sow it and repack the wound as before. This time, in contrast with the previous trial, it followed a perfectly normal and successful course, and the organism was eventually recovered from the pus.

Repeated experiments of the same nature gave identical results, and it seemed therefore that we had laid our hands upon the vital factor in the success of salt-pack treatment, namely, the fostering of a particular anærobic bacillus in the wound. All the same, it was still uncertain what part the salt played in the matter, and how far its lymphagogic action was responsible for the results; also whether the repacking process had itself an influence. This was determined by eliminating salt altogether in certain test cases, and substituting inert packs in the first instance, employing either sphagnum moss or simply plain white gauze. The results were identical in the process of recovery with the normal salt-bag treatment. Now we are in a position to say that the lymphagogic explanation of salt treatment is at least unnecessary, for identical results can be obtained with a perfectly inert dressing, provided that our proteolytic bacillus be present. The bacillus alone appears to be the curative agent, and this in spite of its association as an anærobe in the same class with several of the most virulent of organisms, e.g. *Bacillus tetani* and *B. perfringens*; and the just fear that has ever attended infection with any anærobic bacteria. However, the whole classification and segregation of anærobes is still so chaotic that it is easy to believe that very deep distinctions may underlie superficial similarities, as is apparently the case here.

There does not appear to be any obligatory relationship between the Reading bacillus and the salt, nor has it any special predilection for a medium of high tonicity. Its limit of toleration of salt *in vitro* is closely similar to that of most pyogenetic organisms—about 5 per cent. In any case it has been shown by investigators of salt packing that the outflow of serum produced is so large that the salt is rapidly leached



THE READING BACILLUS

A. Stained with silver to show the peritrichous flagella.

B. Series showing spore formation. Gram's stain.

(1) Young, dividing bacillus.

(2) Granulated form, observed in broth culture.

(3) Dark-staining material beginning to accumulate [illegible]

(4) (5) The young spore formed and filled with dark-staining [illegible]

(6) Centrally placed spore, mature.

(7) The typical mature sporing form. A dark granule is [illegible] each end of the spore.

(8) Type of bacillus in older cultures (5–7 days). The [illegible] disappear.

(9) The final stage. A spore liberated from the remains of the [illegible] body.

C. Mature sporing individuals as seen in a hanging drop.

This corresponds with No. 7 above, which is taken from a stained [illegible] the living bacillus the body is torpedo shaped, and the [illegible] bulge the sides outwards as it appears to do in the dry film.

D. A typical surface colony on agar. (3–4 days.)

A, B, C × 3000. D × 5 diameters.

out of the bags, and the concentration in the wound at the end of twenty-four hours is not above 2 per cent.

If, then, the Reading bacillus is simply a sporadic organism, accidentally fostered by salt-packing, what is its actual rôle in effecting cures?

The increasing use of excision, imperfect though that method is, shows that the vital importance of the dead tissue in a wound is becoming more fully realized. However small the trauma inflicted, some devitalized tissue there must be, and the efficacy of either antiseptic or saline treatment diminishes in proportion as the amount of necrotic material present rises, so that the cleansing of a wound really implies the removal of the dead tissue, rather than its associated micro-organisms. Antiseptic treatment, on the other hand, aims simply at the poisoning of the organisms present, and if the dead matter be abundant this is just what no antiseptic surgically applicable can do. The dead tissue forms the basis which gives the infecting organisms foothold in the wound. So long as any organisms at all remain alive, shielded, it may be, from antiseptics by the adsorptive powers of the albuminoid masses in which they are embedded, the infective attack steadily continues. Decomposition products of general toxicity may be liberated, and opportunity afforded for the elaboration of the specific bacterial toxins with which the adjacent but healthy tissues are bombarded, their resistance lowered, and the area of septic infection automatically spread. To remove the dead tissues is to rob the enemy of his supply base, and thus to circumscribe the development of the invaders within limits which the resistant powers of the body itself can quickly deal with, if they are properly called forth, and not interfered with by the artificial irritation of antiseptics. This relief of the tissues from continued intoxication is, of course, what is

aimed at through excision, but it is obvious that a strongly proteoclastic organism which is non-toxic presents greater possibilities for the removal of dead cells than the surgeon can ever hope to rival. It can dissect cell from cell, and removes practically all the devitalized tissue in a few days, destroying the hold of the pathogenic organisms without inflicting any fresh injury which might in its turn become the gateway of renewed infection. The important thing is that the products of its proteolysis, evil though they appear to our senses, are, chemically speaking, simple and non-injurious to the tissues, so that by the time the salt packs are removed the body has been almost completely relieved of the strain of the toxin infiltration, and the dead tissue is reduced to a mere shred or two, which may be detached at once. Thus all the forces of repair are enabled to work unembarrassed, and strong granulations rapidly form. Proteolysis, then, is to be regarded as the foundation of the method, and towards its furtherance investigation should be directed. Not that this is the only time that proteolysis has been urged as a satisfactory method of ridding the wound of dead tissue. It has been strongly advocated by Morgan, Saner, and Schlesinger as the result of practical experience in France, and we understand that the Germans also have used some peptonizing ferment as a wound dressing; but a method which makes the wound itself the focus of enzyme production, and thus avoids any trouble of renewal or possible imperfection of application has an intrinsic superiority.[1]

[1] It is interesting to remember that the leaves of the Butterwort (*Pinguicula vulgaris*), which secrete a peptonizing enzyme, have been immemorially used by the shepherds of the Alps as a cure for ulcers on the udders of cows. It is possible that many seemingly irrational beliefs in folk-medicine, such as cow-dung therapy, may find an explanation in the activities of proteolytic organisms, as in our present case.

Our own laboratory investigations have been largely intended to elucidate the physiological conditions governing the growth and activity of the bacillus and its relation to the pathogenic organisms and to antiseptics, which we must speak of shortly. The treatment which has so far given the best results is simply that of sowing the wound (after washing out with saline or water) with a culture of the organism either active or in the passive sporing state, it does not matter which, and then packing either with salt, if the wound be deep, or sphagnum moss in the case of wide-open injuries. The only reason for the suggested differentiation is that sphagnum has a tendency to swell in contact with serum unless it has previously been well soaked, and this in a narrow cavity may cause pain. If it has been soaked and wrung out of sterile water it may be used just like the salt-packs, whichever is most convenient, there is no difference in effect.

With salt the pain is transient, and the heavy outflow of serum very soon soaks the dressings, reducing greatly the strength of salt in contact with the tissues. One point must be carefully attended to. The wound must be quite thoroughly opened up, so that the culture and the packing may have free access to every crevice. Failure can invariably be traced to insufficient opening, or to the presence of some unsuspected sepsis progressing elsewhere unchecked. Without opening and proper packing success cannot be looked for. It is valueless to inject the organism into a closed space, and, as gas is formed in the process of proteolysis, may even be dangerous. When the packs have been removed and things have gone well there is no need to renew them, but simple saline dressings may take their place, and measures be taken for closing the wound in the usual manner. This is usually an

easy matter, as the surface is left in ideal condition for junctioning. Cicatrization is uniformly satisfactory. The possibility of secondary infection disappears with the last slough, and the remaining spores of the Reading bacillus are destroyed by the blood cells once the dead matter is removed, so that no special technique is needed to get rid of them.

Here then we have the paradoxical claim that septic infections may be overcome by the introduction of another bacillus into the infected centre, and the establishment of anærobic conditions therein. We have had before us cases with a very wide range of infections, all of which have been carefully followed out, and although we have not had any case of active gas-gangrene to deal with, the salt-pack treatment has been found by others to cope with such cases just as efficiently as with the ærobic infections which are more common. The same can be said with regard to secondary hæmorrhage, which is very satisfactorily dealt with by salt-pack treatment, although digestive action near an injured artery, together with the fact that Reading bacillus digests blood clots, would really seem thoroughly improper if we allowed ourselves to be guided by a priori ideas. Here again experiment outruns hypothesis.

The extreme simplicity of the method is ideal under war conditions. There is no need to wait until the casualty can be removed to a base, or to England, before constructive treatment is commenced. At the advanced dressing-station is none too soon to start, instead of leaving men, with inadequate attention, to go from bad to worse. Even without the initial possibility of surgical opening up of the wound, all that is primarily required is that an ampoule of the culture should be broken over the injured part and dressings

of soaked sphagnum[1] applied and bound on. *Sterility simply does not matter* if the Reading bacillus is introduced, though the usual precautionary injection of anti-tetanic serum could not safely be omitted. Under such treatment sepsis will get no chance, for the controlling agent is already holding the field, and active repair will proceed, even though the case be left absolutely without attention for more than a week. Instead of men reaching base hospitals at the lowest ebb of vitality, they would be already well upon the up-grade, all the advantages of which need no emphasis.

The progress of infection in the cases under treatment has been carefully followed out, and it has been invariably found that the infecting bacteria were nearly, if not quite, as numerous when the packs were taken out as when they were put in, although the proteolysis of the necrotic matter which had been their breeding-ground had put an end to the septic conditions. What made this the more interesting was the rapid drop in temperature and pulse, beginning usually on the third day. The patient feels relief, and the return of normal regularity of sleep and appetite some time before the completion of the proteoclastic cleansing of the wound, indeed just after its commencement; and although the solution of the dead tissue must be regarded as one of the principal benefits of the method, it looks as if it were not indeed the primary one, but that something more rapid takes place as well. Take into consideration the view that the bacterial toxins are albuminous, and it is evident

[1] Colonel Gray has recently found that packs of pure paraffin are just as efficacious as Morison's B.I.P.P., which is as much as to say that the antiseptics in that compound are without positive significance. This suggests, though we have no direct proof of it, that the action of the Reading bacillus may be traced in both these methods of procedure, which have the effect of closuring a wound in an anærobic manner.

that the proteoclastic activity of the bacillus may be directed to their hydrolysis as well, thus ridding the patient, from the start, of that bombardment of toxins which makes such a drain upon the resistance of the system. There is no bacteriolytic effect upon the pathogenic organisms arising from the action of Reading bacillus. That can be shown by prolonged symbiotic culture with both living and dead organisms. The numbers, after reaching a maximum, remain sensibly constant to the end of the experiments, which agrees with what has been previously mentioned as occurring in wounds under this treatment. One is not therefore dealing with a case of organismal antagonism, if such a thing really exists among bacteria, and the explanations of Rumpf's *B. pyocyaneus* treatment of enteric are not valid here, unless that too depends, in reality, upon the protease of the curative organism.

When we turn to the action upon toxins the results are totally different. I regret that I am not at liberty as yet to give full publicity to the results obtained, but they may be briefly outlined thus:—

Taking the toxins of tetanus and diphtheria as two of the most virulent, and therefore most suitable for experimental observation, it has been found that contact with the Reading bacillus so reduces the toxicity that animals will withstand up to one hundred times the minimal lethal dose without serious inconvenience, while control animals are killed by even less than the specified minimal dosage. Similar results are produced with the anærobic *B. perpingens*, though they cannot be pushed so far owing to the large doses required. This amounts almost to definite proof that the toxins, being protein by nature, are split up by the proteoclastic organism into derivatives of a much simpler and non-toxic order, thus confirming recent

work on the proteolysis of the vegetable tox-albumens, ricin, abrin, &c. If this be true, it is evidence of a very generalized power of protein-attack in our bacillus. To make the matter more certain, the toxoclastic effect of (comparatively) pure tryptic enzymes has been tested, with *precisely similar results.* The view we have suggested is borne out by such results. The earliest effect in the wound is apparently the breaking down of the tox-albumens, with the consequent immediate release of the body from intoxication, long before the process of removal of devitalized cell-tissue is completed. With such an agent septic infections hardly matter, they are cut off behind and before, and, if taken soon enough, get no chance even to establish themselves, no matter how virulent they be. The histological observations of Bashford show that the cocci and ærobic bacilli infest the upper layers of dead substance in septic wounds, but that the chief seat of anærobic organisms is below them, next to the uninjured cells, forming, as the Reading bacillus literally does, a screen between the system and the other bacteria.

Clearly we have in these observations of toxolysis a phenomenon of much wider import than that which concerns wound treatment only. The therapeutic significance of these results yet remains to be seen, but if bacterial toxins can be neutralized by the action of tryptic enzymes it opens a new field for research which may well prove of the greatest value to humanity.

Among the very various antiseptics applied to wound treatment, one only stands out by virtue of its proteoclastic properties. This is Eusol, a solution of chlorinated lime and boric acid, which has only very slight germicidal powers,[1] but which proves unusually suc-

[1] Given a solid meat pabulum, Reading bacillus will grow in the presence of

cessful in irrigation treatment, chiefly, as some advocates contend, because it dissolves sloughs. Of course for the simple question of wound treatment an enzymatic reaction possesses marked advantages over a simple linear chemical one, such as the action of Eusol, but the interest here lies in the apparent power of Eusol also to attack toxic proteins, since Dean, in Manchester, has shown that it reduces very markedly the toxicity of vaccines of the Shiga dysentery bacillus. What is more surprising is that animals inoculated with these de-toxicated vaccines are immunized in just the same way as by the unaltered toxin. Now if this be the case with Eusol, how much more is it likely to be true of tryptic enzymes with their vastly greater proteolytic and toxolytic activity.[1]

I would suggest that to this phenomenon of tryptic toxolysis we may look for very great future extensions of the scope of active immunization against bacterial infections.

Again, Lorrain Smith, Ritchie and Rettie, of Edinburgh, have found that intravenous injections of Eusol are of great value in combating septicæmic and toxæmic conditions, and they have widely urged their employment. This seems to be merely another aspect of the same toxolytic effect, and, as before, one feels inclined to point to the superior powers of the proteolytic enzymes and plead for their trial in the same manner. Indeed, taken in conjunction with Abderhalden's discovery of a proteolytic enzyme in red blood corpuscles, as well as the evidence brought forward by Achalme, P. L. Marie, and others, of the

undiluted Eusol. As with other antiseptics, however, the apparent resistance of the organism used for experiment depends strictly upon the numbers introduced, a fact generally overlooked.

[1] Those desirous of further information are referred to a paper by Donaldson in the *Jour. Path. and Bact.*, Vol. XXII, No. 2, 1918.

powerful protease contained in myelogenous leucocytes, and, further, the increase in peptolytic enzymes obtained in the blood serum by albuminous inoculations, one cannot avoid a suspicion that we may here be dealing with part of the mechanism of natural immunity, and that the various protective substances met with in specific sera are no more than various stereometric modifications, specific to certain substrata, of a proteolytic enzyme of normal blood; in which case we might produce *passive* immunity at once, in septicæmias, by the intravenous inoculation of widely active proteoclastic enzymes of one sort or another, such as the filtrate from Reading bacillus cultures rather than by the roundabout method of introducing the specific enzyme in the serum of another animal.

The same principles may be extended to cover the case of enzymic or veninous assaults upon the system, since it appears probable that a protein group is an essential part of their molecules too.

There are other possible extensions. Basing ourselves upon a proteolytic theory of serum immunity, one may regard anaphylaxis as the result of an abnormal reversal of the usual hydrolysis, leading instead to accentuated *synthesis* of the introduced toxin, the eventual balance of the reactions being sensitive to extremely small additions of the original substance from without.

Such questions lead us far from the treatment of war wounds, but they arise spontaneously from the legitimate subject-matter of this paper, which points directly towards them, and it is too much to expect a mere human being to turn his back deliberately when such glorious, if perhaps distant, prospects unfold themselves to his view, with their ambrosial suggestion of great good to come.

It only remains to depict in a few words the personality of the Reading bacillus itself. Morphologically it is a large gram-positive organism with rounded ends, which forms a large oval spore, either subterminally or, less frequently, centrally, after thirty to forty hours incubation at 37° C. At ordinary temperatures growth is very slow. In broth cultures chains are frequent, and beading of the individual cell is sometimes visible.

The illustration here reproduced gives some idea of these characters and of the progress of spore formation in a young culture.

Unfortunately morphology is very little to go by, since half a dozen other organisms of quite divergent properties are positively indistinguishable from our organism under the microscope.

On agar characteristic colonies are formed, with a small dense nucleus and long, spreading fimbriæ all round. It is principally by noting these that the organism may be picked out from a mixture, though its great heat resistance is a help, since the spores of few other anærobes will tolerate an hour's boiling.

In meat broth there is little change before the third day, when blackening first becomes appreciable. Subsequently the blackening and solution of the meat proceed rapidly, with the production of evil-smelling gas, until the meat is about three-quarters gone. At this point the products of reaction accumulate under ordinary cultural conditions so as to put a stop to further growth. The addition of an adsorbent will prolong it somewhat, but never to complete solution of the medium. After about a week proliferation ceases, all the bacilli form spores and settle to the bottom in a white layer, leaving the fluid clear and abating the smell. The spores can be dried on cotton-

wool and preserved so for at least six months, though after a period like this their germination is slow.

Into the chemistry of this proteolysis it is no part of my scheme to enter here, though a certain amount is known about it. The most interesting point is that the enzyme or mixture of enzymes at work is diffused from the living organisms, and can therefore be separated from them without much difficulty and its properties investigated. It is surprisingly weak, and liquefies gelatine and white of egg only very slowly, so that its value in the wound must depend upon its constant formation in situ.

The Reading bacillus is classed with the group of proteolytic anærobes, though the taxonomy of these micro-organisms is far from satisfactory. The group is distinguished for the potency of its members, including, as it does, two such plagues as *B. tetanus* and *B. œdematis maligni.* Such company casts a gloom of suspicion on any bacillus, however well behaved, especially as it is morphologically identical with the last named, and indeed may be nothing more than an atoxic form of it. Happily, however, there are other more respectable creatures in the group as well, and with one of these, the so-called *B. sporogenes* of Metchnikoff, Reading bacillus has probably the closest relationship of all. This relative has similar, though less potent toxolytic abilities. Curiously enough, this power is not common to all the proteolytic anærobes; some, even among the most violently proteolytic, are completely lacking in it. It is seemingly a closely-restricted property, peculiar to a very small number of organisms, and not necessarily associated with powers of general proteolysis.

And where does the bacillus come from? Proximately from the air, there is little doubt; but ultimately, we don't know. It has been identified from

two soils, with a certain amount of doubt, and it is at any rate not very abundant in the soil. Nor is it found in the intestines in more than 1 to 2 per cent of persons. Very likely the soil is its permanent repository, but it only gets a chance to luxuriate where wounds and dead animal tissue abound. Hence certain places will get saturated with it at certain times, and in such a place, by great good luck we found it.

R. C. M.

Substitution of

RAW MATERIALS—PAPER

In the present article no attempt will be made to trace the actual economic phase which is arising as a result of the indiscriminate submarine campaign. The pinch is being felt, no doubt, in various directions, but as yet we are far from the point at which we shall be compelled to use our best ingenuity and skill in the provision of substitutes. Even such shortage as exists is partly masked by our as yet unexhausted capacity to economize or do without—an elasticity to be accounted for as a lucky if undeserved legacy from extravagant pre-war habits.

No one outside official life, who has not lived since the war in enemy territory, or at least in one of the hard-hit Scandinavian neutral countries, can have any real conception of what has been done, or what can be done, to meet shortage on the grand scale. Government has never encouraged the diffusion of accurate information on this subject, nor has the public at large insisted on having it. Except in very restricted fields little has been done to explore the possibilities of substitutes. The national effort has taken another form, that of destroying submarines and providing tonnage. Substitutes are not improvised in a day, and this lack of foresight is to be deplored on various grounds.

The object of this chapter is by using the existing shortage in certain raw materials to illustrate the

essential nature of the relation which exists between a raw material and the manufactured product. Speaking as a botanist, who is naturally more interested in the former than in the latter, one has certainly been prone to overlook the extraordinarily intimate relation that exists between the nature of the raw material and the details of the process to which it is submitted in conversion to the final state. Manufacturing processes usually consist of a series of very complicated operations which require high technical skill combined with very special plant. When a raw material is changed, the process of manufacture no longer runs smoothly, but is seriously disturbed. This can be illustrated by a homely example.

Every pipe smoker knows the inconvenience caused him when he has to substitute an unfamiliar brand of tobacco for that to which he is accustomed. Pipe smoking stands for a manufacturing process, the details of which vary from one brand to another. The weed has to be packed differently in the bowl according to the way the tobacco is cut and pressed. Then there is the lighting of the pipe. Fine-cut tobaccos catch fire at once, but coarse-cut varieties often demand the use of two or three matches to get properly alight. Moreover, the draught varies with the brand. With a fine-cut tobacco an occasional gentle puff is all that is required to keep it alight, and the mind can be concentrated on other things; the devotee of the coarser cuts, however, is kept continuously at work in maintaining the forced draught which such tobaccos demand. The result of changing brands is that the fine-cut man takes days or weeks to learn the knack of keeping a coarse-cut tobacco alight, whilst the coarse-cut man will consume a pipeful of fine tobacco in a few moments—and also burn his tongue.

Proceeding now to the subject-matter, paper and the paper shortage.

The art of paper-making is amongst the most beautiful which technology has evolved, and will serve as well as any other to illustrate our purpose, viz. the intimate relation existing between the finished product and the process of its manufacture on the one hand, and the properties of the raw material on the other.

Broadly speaking, paper is a web formed by the maceration of strands of vegetable fibre or of wood so that the unit elements come apart; subsequently these are caused to combine into a felt by precipitation from a watery broth on a woven wire cloth.

The invention of paper is attributed to the Chinese, and dates back to the early years of the Christian era.[1] From China it passed to Samarkand about A.D. 700, and found its way to Spain by the Moors in the eleventh century. Thence it spread over the countries of Europe. One of the earliest extant examples of the use of paper in Europe is a letter from Raymond, son of Raymond, Duke of Narbonne, to Henry III, King of England. The date of this letter, which deals with a matter of no importance, falls between A.D. 1216–1222. It is preserved in the museum of the Public Record Office. The paper of this specimen, as in the majority of early papers, was made of flax. In other words, the paper trade of those days, as it does in part to-day, depended for its staple raw material on a by-product of civilization, i.e. rags.

The process of manufacture was rude and simple when compared with that obtaining to-day. The

[1] Papyrus, in use at a much earlier date, is not paper in the modern sense. It consisted of longitudinal slices of the pithy stem of the paper reed, *Cyperus Papyrus*, pressed and dried together, and the surface smoothed to receive the ink.

rags were allowed to ferment, and were then boiled in an infusion of wood ashes. The resulting pulp, after being anchored in streams of running water to wash out the alkali, was beaten by hand till it reached the proper degree of maceration. The rectified pulp was then diluted with water in vats, and taken up in sieves, so that the water drained away, whilst the fibres, under skilful manipulation, settled down to form the web of paper. Sheet by sheet the paper was pressed between felt, and hung up to dry. Such methods sufficed for many centuries, and, so far as the quality of the product is concerned, still hold their own. With lapse of time, and the natural growth of population, paper came to be produced in increasing quantities, beating by hand was replaced by an automatic machine termed the Hollander, but the great impulse came through the invention of the paper-making machine associated with the name of Fourdrinier, by means of which the pulp was run on to a travelling fine-wire web, so that it could be treated by a continuous process without breaking bulk.

The spread of the reading habit, stimulated by compulsory education, and exploited by editors and publishers, created a demand for paper which could not be met by the conversion of rags alone. So far as this country is concerned the increased demand was met in the sixties of last century by utilizing straw, which in due course was displaced by esparto grass (*Stipa tenacissima*) from North Africa and Spain. By the nineties the manufacture of pulp from wood, and especially the wood of conifers, had become general.

The esparto industry is in effect a speciality of the British paper-maker, who for many years has imported some 200,000 tons of the dried grass.

On the continent of Europe straw largely takes its

place, and fine papers are got by blending straw and wood pulp where we blend esparto and wood.

The world's pre-war consumption of paper was roughly 8,000,000 tons, half manufactured in America, half in Europe. Of this total four-fifths (i.e. 6,500,000 tons) was derived from wood. The British requirements were about one-sixth of the world's production (i.e. 1,350,000 tons), and the greater part of it was fabricated in this country from imported pulp. The proportion of wood pulp used in English paper manufacture approximates to the world's proportion, i.e. four-fifths.

It follows from these facts that wood pulp dominates the position; this it does in virtue of its derivation from a raw material which grows thickly on the ground in pure formations (virgin forests). Owing to its cheapness of production, few raw materials can compete with wood pulp, especially for general purposes. Even India, with vast areas of potential pulp in its bamboo jungles, is unable to exploit these rich natural resources. India's paper trade is based on waste products, such as rags, old rope, jute bags, and waste paper, together with a certain amount of the native Bhabur grass (*Ischæmum angustifolium*). More than half the Indian requirement is stated to be imported as manufactured paper derived from coniferous wood pulp. It is to be expected, however, that, with the exhaustion of the world's virgin coniferous forests, bamboo will become an important, if not the principal, source of pulp.

So considerable is the importation of wood pulp in Britain that it forms an appreciable part of the whole timber problem. The figures involved are given in the following table:[1]—

1 It is assumed that one net register ton of shipping corresponds to two loads or tons of timber of 50 cubic feet.

	Average Annual Imports in Tons of Shipping (1909-13).
Timber	5,000,000
Pulp	500,000
Manufactured Wood	150,000

Total—5,650,000 tons of shipping.

The shipping required for this service represented 13.1 per cent of the total shipping entered; it is slightly in excess of that required for our grain imports, which was 12.1 per cent of the total shipping.

Under these circumstances it is evident that if tonnage should be deflected elsewhere, or destroyed, the timber and paper trades would be profoundly affected. This is, of course, precisely what has happened, and, so far as timber is concerned, we have been thrown on our own scanty resources. Even were there enough wood to spare for pulp-making, it would take much labour and time to adapt the mills; for, depending as they do on imported pulp, they are—apart from a small minority—unprovided with the necessary boiling and recovery plants. Moreover, they are not placed at the proper spots for dealing with the problem economically.

The existing shortage of paper, which in May, 1918, corresponded to a deficit of 75 per cent, is acutely felt throughout the trade, and especially in the cheap news prints. At the same time there is a greater demand for newspapers than ever, whilst official requirements are enormous.

Roughly speaking, paper materials from abroad are rationed to consumers on the basis of a proportion of the pre-war consumption. The method, though undiscriminating, and affecting equally the various users of paper, appeals to the rough sense of fair play of the community, and is probably administered with

relatively little friction. After all, who is going to decide between the claims of *John Bull* and a new work from the pen of Mr. G. B. Shaw?

To meet the shortage there are three measures available: (1) Economy in use; (2) the more complete organization of existing home sources, especially in the collection and conversion of waste paper; (3) the opening up of home sources at present not utilized.

It is this third category alone that interests a botanist, and which will be considered here.

Offhand it might be expected that the paper-maker would be running around everywhere, in a state bordering on frenzy, to discover new sources of materials; such an anticipation is, however, contrary to the facts. In common with all producers of commodities, which though not to be reckoned as munitions of war are yet in universal demand, we see that the paper-maker, in spite of his reduced supplies and depleted staff, is still able to meet his wage bill and to pay a sufficient, and sometimes an increased, interest on the capital invested in his business.

So long as a declining output is rewarded on a scale which equals or even exceeds that of normal times, it is contrary to average human nature to exert itself strenuously to raise that output. In other words, up to the present time the compelling inducement has been lacking to discover new sources, and more particularly such as lend themselves to conversion into paper without drastic modification of existing plants.

Moreover, change is resented, and nowhere more than in the paper trade with its high sense of craftsmanship and good technique. Anything which prevents the gratification of this sense is hateful.

Nevertheless, paper is altering, as may be seen in the qualities used for the same purposes now and in

pre-war days. More straw is being used, and with it blemishes creep in. These a layman might not think important, but the paper-maker does not share that view. When settled conditions return he will produce once more the old high qualities. As a craftsman he could not do otherwise.

Still, as elsewhere, adventurous spirits are not lacking, and trials of a variety of fibres hitherto untried by paper-makers are in progress. Such experiments will serve to illustrate the fact that there is no such thing as true substitution. When a raw material is changed the finished product is changed; so too must be the established method of manufacture at nearly every stage.

We may consider briefly the stages in the process by means of which the web or felt of cellulose termed paper is obtained.

The raw material—let us say a grass—has to be collected from its habitat, dried, baled, and transported to the mill. Here, after cleansing, it must be boiled in soda or other suitable chemical agency to remove the non-cellulose, and also to dissolve the matrix which holds the fibres together—what botanists call the "middle lamella". The product of boiling has to be washed and bleached, and then follows the elaborate technical process of beating, in which the diluted pulp circulates in a trough between revolving knives or plates, which can be adjusted to effect a variety of ends, having the general object of rendering the ultimate units of the pulp better fitted to play their allotted part. By fraying out the ends of the fibres they will felt the better; if the fibres are too long, they can be cut into shorter segments; or, by crushing, the fibres become more intimately charged with water—hydrated—so as to give a homogeneous texture as they join together and dry.

Next, the beaten pulp, when properly mixed, is sized and loaded with some filling substance, such as china clay, and, after various rectifications to clean it or to remove local knots of stuff, the pulp is delivered in a thin liquid sheet on to the paper-making machine—the wire-wove travelling belt.

Here, as the water drains away, the fibres of the pulp take up their final positions and felt together. The act of felting is promoted by shaking mechanisms which overcome a tendency which the fibres possess to lie parallel to the direction of flow.

Next the sheet is dried, partly by gravitation, partly by suction from below, and partly by heated rollers, the rate of travel of the web being adjusted to the rate at which the water is given up.

Further operations to which it is subjected include water-marking, sizing, the removal of superfluous size, the smoothing of the surface, and calendering. Finally the paper is cut into the desired widths and lengths, counted, and packed.

Now the chemical and physical qualities of the paper are related in the most intimate way to the original properties of the fibre, modified by these various operations.

Esparto has a fine fibre of circular section and small central cavity. It resists excessive hydration, and quickly parts with its water on the machine. Its fineness and consequent flexibility confers on the pulp admirable felting qualities for binding the sheet together with a uniform texture. As the fibres do not rest too closely over one another, but stand up, esparto gives "body" to a paper.

Wood pulp, having fibres flat in section, which lie close over one another, gives a non-porous paper of more continuous texture. As the fibres undergo hydration, becoming gelatinous, they become firmly

compacted or cemented together. With such continuity of substance the sheet readily takes a high finish.

Blended with esparto, wood pulp makes an ideal mixture for many purposes.

There are two great divisions of wood pulp, the chemical and the mechanical. The former has been boiled in soda or other chemical agent to disintegrate it and clear it of lignin. It forms a pulp suitable for inclusion in the best papers, and, owing to the porosity which its membranes acquire by the extraction of the lignin, it lends itself to hydration in the beater.

Mechanical pulp, on the other hand, has never been boiled. It is formed by grinding the wood into small fragments in a stream of water. It belongs to the lowest order of paper-making materials, and is without any capacity for felting. Moreover, as it contains the unaltered lignin of the wood, papers formed of mechanical pulp rapidly undergo oxidation, becoming discoloured and brittle.

Mixed with a minimum of chemical pulp, which supplies the qualities it lacks, mechanical pulp finds enormous application for news and common printing papers.

Though far from being a high-class raw material, mechanical pulp is good enough for the purpose to which it is put, namely, to form a tissue strong enough to go through the printing-press and hang together till read. It is an ephemeral product, and should not be regarded from any other point of view.

At the present time an attempt is being made to use sawdust as a substitute for mechanical pulp, and newspapers have already been produced into which sawdust enters. The application is a promising one, as more sawdust is now produced in Britain than ever before, in consequence of the wholesale felling

and conversion of our native timber. Now that the problem has been defined, technologists may be relied on to devise a process by means of which sawdust may be ground into a form thoroughly suitable for the purpose of a paper ingredient.

In casting about for home-grown fibre plants to supplement existing sources, a suitable quality of fibre is only one of several conditions that have to be satisfied.

The plant must also be abundant and readily harvested; preferably it should grow in close pure stands, ripe for the scythe or mechanical harvester. Moreover, the material must be easy to clean, for the inclusion of dirt in the pulp is obviously a serious defect in a paper-making material.

Several indigenous plants meet these requirements in part, and deserve serious consideration.

The pulping of timber in our country is out of the question owing to the scantiness of the supply. Whether the matter will become a serious proposition when our system of forestry is reformed is for a future generation to decide.

Again, the employment of the straw of wheat and other cereals is no doubt attractive, for this material comes into existence in order that there may be grain, to which it stands in the relation of a by-product. Moreover, it grows in pure stands, has to be reaped, and is as clean as any vegetable product well can be. The objection to the use of straw is twofold. There is the minor objection that its use presents certain technical difficulties, which, with application, could probably be overcome. The main objection is more fundamental. Straw is so valuable on the farm itself in our present system of farming that it is open to question whether the unlimited use of straw is advisable in the interests of agriculture itself. How-

ever, machinery is creeping into the land, and this may revolutionize all standards.

Triticum repens, the couch-grass, the familiar noxious weed of arable land, is a plant with a running underground stolon which is reported to provide a fibre of great tenacity. The alleged drawbacks of couch-grass are the expense of collection and the very large amount of dirt which accompanies it. And, no doubt, if the collection of couch-grass be regarded as an independent industry, the cost of production is high. If, however, the farmer views it as his bounden duty to rid his fields of this pest, its collection is then but a part of the farm routine, and any reasonable price which the paper-maker can afford to pay will be of the nature of a subsidy to assist the farmer in the cleaning of his land.

But even if we assume these difficulties to be solved, the further question arises whether, if it be periodically and industriously removed from the land, the supply may not shrink away to almost nothing in a certain number of years. That, no doubt, is a possibility.

A more serious proposal is the use of the marram grass of the sand-dunes (*Psamma arenaria*). Small samples have been favourably reported on, and larger trials are being undertaken. The crop is a very clean one, and the yield of fibre about 33 per cent on the dry weight of the grass. As it grows on virgin sand-dunes the grass is unsuitable for paper, because the cut includes not only the growth of the current year, but also the dead and useless remains of former years. Consequently the first mowing has only the value of a preparatory measure to secure a yearly cut of useful grass. In some localities (e.g. Newborough dunes, Anglesey), marram is cut for mat-making, and it would appear that in such cases a certain amount

of grass of unsuitable length for the primary purpose is available as a waste product, and could be passed on to the paper-mill.

Should the question ever be seriously pursued, it would be necessary to plant the dunes; for, when left to nature, marram does not grow in anything approaching its maximum density. The planting can be put through at an inclusive cost of £5 an acre, and by the third year should be ready for a first cutting. Two tons would be a normal yield per acre. In cutting marram it is advisable to leave narrow belts of the grass uncut (e.g. 1 foot wide every 12 to 15 feet) to prevent the sand from being blown away from the stubble.

The question whether the utilization of sand-dunes to grow pine woods may not be a more profitable investment than the cultivation of marram grass will have to be considered in connection with the various circumstances, location, &c., of each individual area. Taking pine woods with a seventy-years' rotation, it would be surprising if the total weight of timber (final yield plus thinnings) exceeded the aggregate yield of grass during the same period.[1]

Spartina Townsendii.—This is a tall-growing grass, which first made its appearance on the tidal flats of Southampton fifty years ago, and has since spread everywhere in the adjacent waters of the Hampshire coast, and has also penetrated into Poole Harbour. In these regions it now occupies many square miles in dense continuous meadows. The circumstances of its appearance and spread are so remarkable as to be practically unique in the recorded history of the world's vegetation.

[1] Taking 5500 cubic feet (= 110 tons) as the complete yield of timber per acre under Scots Pine after seventy years, the average annual yield of marram grass would require to be 1.57 tons.

A century ago the only species of Spartina known in Europe was *S. stricta*, a low-growing species common on mud flats from Devon to Lincoln and on the Continent. In 1836 this was joined by a second species, *S. alterniflora*, supposed to have been introduced accidentally by shipping from America. Its occurrence in Southampton Water and at one other spot, the mouth of the River Adour, at the southern end of the Bay of Biscay, was well known to botanical geographers in the middle of last century.[1] In 1870 a third species, *S. Townsendii*, the subject of this notice, was found also in Southampton Water, and it is this form which has spread in recent years in the marvellous manner just indicated.

There is no reason for believing *S. Townsendii* to be an introduced form, for it is not known to occur anywhere else in the world. The current hypothesis, due to Dr. O. Stapf, is that it originated in situ as a naturally produced hybrid between the two other species (*S. stricta* and *S. alterniflora*) already on the ground, a hypothesis which gains weight from the fact that in the Adour River locality—the only other spot where these two species occur together—a fourth form (*S. Neyrautii*), having much in common with *S. Townsendii*, has made its appearance. The presumption is that both these new forms are natural hybrids, but the matter requires corroboration at the hands of some competent breeder.

It is probably safe to estimate the present area occupied by *S. Townsendii* at 20 square miles, an area which is continually extending. The ground it covers is soft mud stretching down from high-water mark some 4 feet vertical. The grass is exposed as the tide runs off, and is accessible for cutting in the ordinary way. It reaches its full growth in the late

[1] A. De Candolle, *Géographie Botanique*, 1855, p. 1053.

summer ($2\frac{1}{2}$ to 3 feet), though the seed does not ripen till November. The grass turns yellow in winter, and remains standing till April or May, when it comes away from the stools, which in due course push the next year's crop.

Since 1916 several samples of this grass have been tried for paper-making purposes, and there is no doubt it possesses capacities in this direction, though it is, of course, premature to specify them in detail. The fibre felts well, and the yield averages 28 per cent on the dry weight of the grass. The nature of the habitat—tidal mud flats—is a novelty in the harvesting of a paper-making material. The mud is so soft that the reapers have to wear mud-boards on their feet, and the application of a mechanical harvester seems to be excluded by the nature of the ground, unless something could be attached to a flat-bottomed punt, and the cutting done at high water. The pulp is liable to contamination by mud adhering to the bases of the grass haulms, but, as this defect shows marked diminution when a second cut is made from an area previously mown, it seems likely that it will become negligible as the conditions are more fully mastered. The pulp hydrates readily and tends to "run wet", but here again experience will show how best it should be treated.

The grass grows very densely, producing, at a conservative estimate, 2 tons dry grass per acre. The total yield in sight in these waters would, if properly organized, suffice to feed a mill in the locality with over 200 tons of material a week, and this could be transported in barges. From an economic point of view the erection of a special mill to deal with the Spartina products would seem to be the best plan.

It is worth noting that an American species, *S. michauxiana*, the slough grass, which grows every-

where in the swamps of the Mississippi and Missouri river systems, was used in great quantities for making boards at Quincy in Illinois. Its properties found favourable notice in this country,[1] but, so far as we know, it has never been imported on a commercial scale.

Another grass, *Phragmites communis*, the common reed, has latterly been laid under contribution, and is now helping to fill the vacuum in the paper-making world. The large size of this plant and the dense stands in which it grows, taken in connection with long experience in harvesting it, mark out Phragmites for adoption as a raw material, provided, of course, that the fibre has qualities of usefulness. In the Norfolk Broads area, where it is very abundant, this grass is stated already to have doubled in price.

The days of shortage appear at first sight to be the golden opportunity for the recognition of such merits as our wild indigenous fibre plants possess, and this, no doubt, is true up to the point of proposals for trials being entertained. But the way of establishment of a new fibre is long and arduous. It has first to be tried along the lines of current routine, and this gradually modified according to experience until the paper-maker discovers the best use to which it can be put. Even should the fibre survive the preliminary trials, great, if not insuperable, difficulties will be met with in organizing the harvesting and treatment of the crop. In a small way a new sort of agriculture has to be learnt, and labour is practically unprocurable at a time when the prior claims of food production, timber, flax, and other war essentials remain unsatisfied. It looks as though mere shortage was an inadequate stimulus to call forth the sustained

[1] Cf. Bowack, Dixon, and Remington in *World's Paper Trade Review*, 23rd April, 1909.

effort required. Possibly our psychology is such that nothing short of absolute want and destitution will arouse it.

In that case we shall have no choice but to continue still further to economize our meagre supplies—perhaps by discriminating between the different uses to which paper is put.

After the war the conditions will change. As labour is set free, tonnage rather than labour will become the limiting factor. And while they last these conditions should prove more favourable to the adoption of new raw materials drawn from our unexploited home resources.

But even in the case of a new raw material which gives full satisfaction in a technical sense, and serves a useful purpose under war conditions, ultimate adoption will depend on whether it can hold its own in competition with existing staples. If paper substantially as good can be prepared from cheaper materials, there will be no chance of the new proposals being entertained.

F. W. O.

INDUSTRIAL EFFICIENCY AND FATIGUE

At the present time we are offered a unique opportunity for investigating problems of industrial efficiency and fatigue. And this for several reasons. The country is full of munition factories where huge numbers of men and women are labouring day and night to produce their maximum output. Now, if ever, the large majority of them are exerting the greatest effort of which they are physically capable, and are in no way subjecting their output to artificial restrictions and limitations. Moreover, most of these munition workers are engaged on repetition work, or they are manufacturing exactly the same article on the same machines day after day, month after month, and year after year. Hence it sometimes happens that the conditions of production remain constant for months and years, with the exception of some alteration of hours. By studying the output of these workers systematically we are therefore enabled to obtain invaluable evidence as to the effect of various lengths of working hours upon the hourly output and the total output. Our object is the practical one of finding the conditions which result in the greatest possible output. We do not want a spurt in output lasting a few days or weeks, but a steady maximum lasting for months and years. That is to say, we want to get all we can out of our munition workers,

but their maximum effort must be so controlled that it does not reduce their health. Directly they begin to get over-fatigued, their efficiency diminishes, and their output goes down. Fatigue is defined by The Health of Munition Workers Committee[1] as "the sum of the results of activity which show themselves in a diminished capacity for doing work". Hence the essential condition of all efficient labour is that it avoids this condition of fatigue which produces a diminished capacity for work. It might be thought that it is a simple matter to recognize such a condition, but this is by no means the case. Extreme fatigue can, of course, be readily identified, but the moderate condition of fatigue which is sufficient to cause some reduction of efficiency is difficult to distinguish from the normal condition of fatigue which almost every genuine worker ought to experience at the end of his day's work. Such fatigue should be recovered from completely, or very nearly completely, as the result of good food and a good night's rest, or the worker ought to be able to begin each day's work in a state of full and normal vigour, with the exception that he generally gets a little more tired towards the end of the week than he is at the beginning, that is, he experiences a slight accumulation of fatigue which he is able to get rid of during his Sunday rest from work.

Over-fatigue in Women.—For reasons which will appear shortly, the condition of over-fatigue is very seldom observed in men, and not very frequently in women. I observed one very striking instance of its occurrence in the women who were employed at a large fuse factory, where there were about nine thousand workers. In the earlier months of the war the usual hours of labour were $77\frac{1}{4}$ a week, or ran for 12 hours a day, five days a week, but for somewhat less on Saturday

[1] Memorandum No. 7. 1916. (Cd. 8213.)

and Sunday. Sunday work was intermitted once a month, or on an average the workers put in about 75 hours a week of actual work, exclusive of meal-times. The women were undoubtedly in a state of chronic fatigue, from which they never had a chance of recovering unless they voluntarily took a holiday from their work. This fatigued condition was shown most clearly in their accident records. I tabulated their accidents for three months when these very long hours were being worked, and for the subsequent two years during which the hours of work were first reduced to about 64½ a week, then to 58½ hours, and then to 54½ hours.[1] Small accidents, especially cuts to fingers and thumbs, are very frequent in women who are turning or drilling various fuse parts, and in fig. 1 is shown the hourly incidence of cuts, calculated per ten thousand workers per week. In 1915, or what may be termed the fatigue period, there were 17 cuts treated in the first full hour of work, but the number rapidly increased from hour to hour till in the last full hour of work of the morning spell 90 cuts were treated, or more than five times as many. This rapid increase was due largely to fatigue, for in 1916 and 1917, when the shorter hours were worked, the cuts increased only threefold in the course of the morning spell. It is true that a part of this increase was due to fatigue likewise, though most of it was due to a speeding up of production, coupled with increasing carelessness and inattention of the workers, owing to thoughts of the approaching dinner break. In the afternoon spell the accidents during the fatigue period were twice as numerous as subsequently, but they fell away rapidly between 6.15 and 8.30 p.m., as the women were so tired that many of them slacked

[1] Cf. Memorandum 21, published by The Health of Munition Workers Committee. 1918. (Cd. 9046.)

off and did little or no work, and so did not expose themselves to the risk of accidents. Taking an aver-

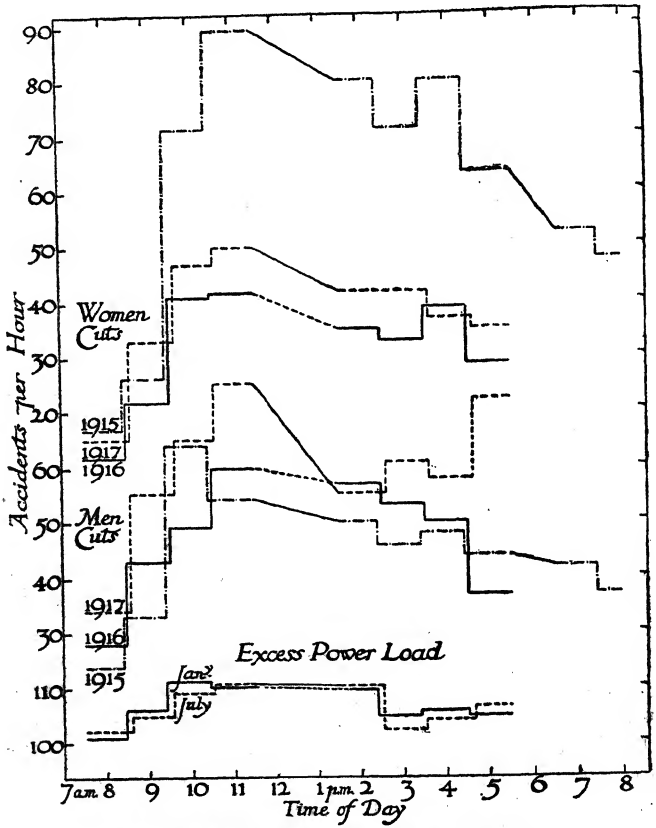


Fig. 1.—Hourly Variations of Accidents and of Output

age of all the accidents put together, the women suffered nearly three times as frequently in the fatigue period as they did in the subsequent fourteen months, when they were working ten hours a day instead of

twelve. This three-fold increase held almost equally for eye accidents, burns, and sprains, as well as for cuts.

In addition to tabulating accident cases, I determined the frequency with which the workers were treated at the dressing-station for faintness, and were restored from their collapsed condition by the administration of sal-volatile. During the fatigue period faintness cases were 9 times more numerous among the women than among the men, whilst subsequently they were only 3 times more numerous. Sal-volatile cases were actually 23 times more numerous in the women than in the men during the fatigue period, though subsequently they were only 3 times more numerous, just as were the faintness cases.

The accident data for men, which are shown in the middle portion of fig. 1, indicate a very different relationship from that observed in women. The curve of hourly incidence of cuts was almost the same in 1915, or the fatigue period, as in 1916, and, if the accidents between 6.15 and 8.30 p.m. be excluded, the total number of cases treated was almost the same in both periods. Hence it follows that the men were able to stand the excessively long hours even though the women could not. In fact, I concluded from this and other evidence that women ought to work only nine hours a day if they are to fatigue themselves no more than men engaged on similar work for twelve hours a day. All the evidence I obtained went to show that there was no over-fatigue in the men at any time, and very little in the women when working a ten-hour day. For instance, the hourly variations of output during the course of the working day showed very little signs of it.

Hourly Output Variations.—I was able to determine output variations in a very complete manner at

the fuse factory by an indirect method. The electric current supplied to each section of the works was registered by a separate watt-meter, and by reading these meters every hour I could determine the exact amount of current consumed. I was able to determine the current required to drive the machinery, apart

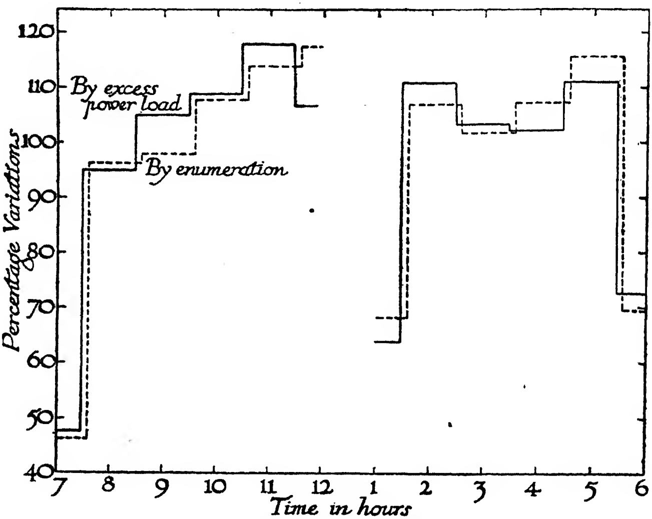


Fig. 2.—Hourly Output of Fuse Bodies

from that required for the actual lathe operations, and I found that the excess power-load determinations made in this way gave an output which corresponded well with the direct observations on output which were made by Mr Neilson Jones, who was working in conjunction with me. It will be seen in fig. 2 that the curves of output of women engaged in the operation of turning aluminium fuse bodies agree fairly well except in the last half-hour of the morning spell.

The difference which then occurred was due to the fact that the women who were under direct observation continued to work right to the end of the spell, whilst most of the other women in the section knocked off a few minutes before nominal stopping-time. The output steadily improved during the course of the morning spell, till it was 21 per cent greater in the last hour of full work than in the first hour. This increase arose from increased efficiency due to practice, and it was observed in greater or less degree among all sections of workers. It was more than sufficient to neutralize any tendency to diminished output which might be produced by fatigue. Even the afternoon output showed only a little indication of fatigue in the middle two hours, but such fatigue effects were completely overpowered in the last full hour of work by the spurt which the workers put on as they knew that rest and relaxation were at hand. The output curves of the men's sections were similar to those of the women's sections, and the mean output of seven sections is shown at the bottom of fig. 1. It was determined on three consecutive days in January and on another three in July, 1917, and it will be seen that the curves correspond well with one another. The only real evidence of fatigue shown by the power-load curves was obtained by comparing the excess power consumed in the four full working hours of the afternoon spell with that in the four full working hours of the morning spell. It was found to be 1 to 2 per cent less, on an average, in the afternoon, and, in that the output of the morning spell was considerably reduced by the lack of full practice efficiency during the first two or three hours, one can say that fatigue in the afternoon had a slightly greater influence in reducing output than had the lack of practice efficiency in the morning.

Output in Relation to Hours of Work.—If, as I have concluded, the men were not unduly fatigued by working a twelve-hour day, or the women by a ten-hour day, does it follow that these long hours are calculated to yield the best output? By no means, as was proved by direct observations on the output of selected groups of men and women.[1] I was fortunately able to obtain the output of large groups of workers week by week over continuous periods of as long as twenty-two months, during which there was absolutely no change in the conditions of production except the hours of work. The articles produced were the same throughout, and of the same material, whilst the machinery was not altered in any way or speeded up. Groups of men engaged in the somewhat heavy operation known as "sizing fuse bodies", which consists in screwing the aluminium fuse bodies into steel taps so as to cut screw threads on them, showed these relative outputs:—

TABLE I—MEN SIZING FUSE BODIES

Statistical Period.	Number of Workers in Group.	Average Weekly Hours of Work.		Relative Hourly Output.	Hours of Work × Relative Output.
		Nominal Hours.	Actual Hours.		
Nov. 8 to Dec. 19, 1915	27	66.7	58.2	100	5820 (=100)
Feb. 21 to Apr. 16, 1916	56	62.8	50.5	122	6161 (=106)
Nov. 6 to Dec. 16, 1916	56	56.5	51.2	139	7117 (=122)
June 23 to Sept. 22, 1917	90	54.1	48.8	144	7027 (=121)

It will be seen that in the November to December, 1915, period, they were nominally working 66.7 hours per week, or they sometimes worked a twelve-hour day and sometimes a ten-hour day, but on an average

[1] Memoranda Nos. 12, 18, and 20 of The Health of Munition Workers' Committee. 1916 and 1917. (Cd. 8344, 8628 and 8801.)

they put in only 58.2 hours of actual work. Taking their relative hourly output as 100, their total weekly output came to 5820. Subsequent to December, 1915, the men worked shorter hours, and in the next statistical period recorded, viz. February to April, 1916, they put in only 50.5 hours of actual work per week, or 7.7 hours less than before. However, their relative hourly output increased in consequence to 122; i.e. their total weekly output was now 6161, or 6 per cent greater than before; but this figure by no means represents their best effort. In the next period recorded, viz. November to December, 1916, the men were working practically the same actual hours as before, but their nominal hours were 6.3 per week less, and the frequent Sunday labour which was imposed on them in the February to April period was completely abolished. Under these conditions they worked much more steadily, so that their lost time, or the difference between nominal and actual hours, was now only 5.3 hours, instead of 12.3 hours per week, and their relative hourly output rose to 139. Their total output accordingly worked out at 7117, or was 22 per cent greater than when the longer hours were being worked. In June to September, 1917, their hours of work were rather shorter still, and their hourly output again went up a little, but their total output was practically unchanged. That is to say, a reduction of the actual hours of work from 58.2 a week down to 48.8 per week, accompanied as it was by the abolition of Sunday labour, caused their total output to go up some 21 per cent.

Equally striking were some of the results observed in women. Table II shows the relative output of 80 to 100 women engaged in turning aluminium fuse bodies on capstan lathes. In this operation they were actively employed every moment of their time, and

TABLE II.—WOMEN TURNING ALUMINIUM FUSE BODIES

Statistical Period.	Number of Workers in Group.	Average Weekly Hours of Work.		Relative Hourly Output.	Hours of Work × Relative Output.
		Nominal Hours.	Actual Hours.		
Nov. 7 to Dec. 19, 1915	100	74.8	66.2	100	6620 (=100)
May 8 to July 2, 1916	100	61.5	54.8	134	7343 (=111)
Nov. 6 to Dec. 16, 1916	80	54.8	45.6	158	7205 (=109)

they had to apply seven cutting or boring tools in succession to each fuse body. In the November to December, 1915, period these women put in 66.2 hours of actual work per week out of a nominal 74.8 hours, and, taking their relative hourly output as 100, their total weekly output came to 6620. After January, 1916, the twelve-hour day was replaced by a ten-hour day, and in the May to July period recorded in the table the women were putting in 54.8 hours of actual work, or 11.4 hours less than before. In consequence, their hourly output went up to 134, and their total output was 7343, or 11 per cent greater than in the twelve-hour-day period. Shortly after, Sunday labour was abolished, and in the November to December, 1916, period the women put in only 45.6 hours of actual work. However, their hourly output so much improved that their total output remained almost the same. That is to say, they produced 9 per cent more fuse bodies than in the twelve-hour-day period, in spite of the fact that they were working 20½ hours less per week.

These and other data which were obtained indicated that within certain limits a reduction in the hours of labour leads to an increase, not only of the hourly output, but of the total output. The correct interpretation of this result is an interesting and important one. It has been suggested to me by more than one

works manager that the explanation lies in the fact that the workers are determined to earn a certain amount of wages, and so they knowingly work harder when their hours of labour are cut down. Even if this were the true explanation, it would surely be worth while to make the reduction of hours, for the running costs of the machinery would be reduced, and the workers would obtain more leisure time; but it is *not* the correct explanation. When a reduction in the hours of work is introduced, nothing at all happens to the hourly output for some weeks, and then it gradually begins to mount up, but it takes four months or more before it reaches a steady level again, or until the workers have got into equilibrium with their altered conditions of work. This altered equilibrium is attained quite unconsciously by the workers. When they are working excessively long hours, such as twelve per day, they soon find that in order to last out through the working week they *must* go slow, otherwise they would soon become so fatigued that they would have to take a holiday from work in order to recuperate. Supposing their hours are reduced from twelve a day down to ten, they continue to work at the same slow rate just at first, but they gradually find by experience that they can work harder and still harder without undue fatigue, and so they slowly speed up their rate of production until they reach a fresh maximum of output such as is just compatible with the avoidance of over-fatigue.

The relationship between hours of work and maximum efficiency is most easily explained by a hypothetical example. Let us suppose that each vigorous and healthy worker starts his day's work with 12 units of energy, all of which he can put into active work if he pleases without over-fatiguing himself, i.e. without getting into a condition from which a good night's

rest does not completely restore his initial vigour. Of these 12 units probably 1 unit is required by the worker to enable him to get to his factory in the morning, and for essential household duties, whilst another unit is required for similar objects in the evening. He therefore has 10 units of energy left, which he can apply wholly to his work if he so desires. Probably in peace times he does not utilize more than 7 units in such a way, and keeps the other 3 units for his games, or for digging in his garden, or frequently he does not utilize them at all, and ends the day in a state of considerable unexhausted vigour; but we will assume that in war time he desires to put every particle of energy possible into his work, and to expend the whole of his 10 units in this way. How can he use them to the best advantage? There can be no doubt that a great deal of energy is expended if a man stands idly all day in a factory without doing any work whatever. The effects of the noise, the smell, and the physical effort of standing for 10 hours would probably account for quite 5 out of the 10 units, or half a unit per hour. Hence there would be only 5 units left to put into active work. Supposing, on the other hand, only 8 hours were worked instead of 10, then 6 units of energy would be available for active work, and if 6 hours were worked, then 7 units would be available. In other words, the shorter the hours of labour the more the energy available for active and useful work, and the less the energy wasted by mere standing about. It might be supposed that in such a case the shorter the hours worked the better; but another factor which acts in the opposite direction has to be considered. Supposing it needs 1 unit of energy to produce 1 article in an hour, it does not need only 2 units to produce 2 articles in the hour, but distinctly *more* than 2 units. The greater the speed of working,

the relatively greater the call upon the physical energies of the body. For instance, it is found[1] that in a man walking at various speeds more than twice as much energy is required per mile of ground covered when walking 5 miles an hour as when walking 2 miles per hour. Hence, if a workman wants to produce a maximum output he must shorten his hours of work as much as possible, so as to reduce the waste of energy arising from much standing about, but he must not shorten them so much as to necessitate a very great speed of production with its much more than proportionate call upon his energies. He must endeavour to hit off a happy mean, involving *some* reduction of hours and *some* speeding up of production, but what the best hours of work and the best speed actually consist in can be determined only by prolonged observation and experiment. These hours necessarily vary considerably with the character of the work performed. We have seen that in men and women engaged in active work such as sizing or turning fuse bodies the best hours of actual work are probably rather less than fifty per week, but in lighter work they rise above this limit. For instance, in the operation of boring aluminium top caps the youths in charge of the semi-automatic machines perform less than two seconds of active work about four times a minute, and for the rest of the time they stand doing nothing. The output data shown in Table III, which were obtained with a group of 15 of these youths, show that when their hours of actual work were reduced from 72.5 a week down to 54.7 hours, their relative hourly output increased only from 100 to 117, and so their total output was 12 per cent less than before. After some months, however, they were able to speed up their

[1] Cf. Douglas, Haldane, Henderson, and Schneider, *Phil. Trans. Royal Soc. B.*, 203, p. 185, 1913.

production sufficiently to obtain a total output which was only 3 per cent less than the previous maximum, but it is probable that they would have achieved an absolute maximum of output if they had worked about sixty hours a week instead of fifty-four hours.

TABLE III.—YOUTHS BORING TOP CAPS

Statistical Period.	Average Weekly Hours of Work.		Relative Hourly Output.	Hours of Work × Relative Output.
	Nominal Hours.	Actual Hours.		
Nov. 15 to Dec. 19, 1915	78.5	72.5	100	7250 (= 100)
May 1 to May 28, 1916	61.5	54.7	117	6400 (= 88)
July 3 to Sept. 23, 1916	60.6	54.5	129	7030 (= 97)

Overtime Work.—To return for a moment to the hypothetical example, we will suppose that the worker who, during a ten-hour day, is expending the whole 10 units of his available energy, is called upon for two hours of overtime work. If he continues to work at the same speed he must draw upon the *capital* of his energy for this extra work, and such an expenditure is extremely wasteful. We will assume that he needs 3 units for his two hours' work, and so next day he starts work with only 7 units of available energy instead of 10. If he continues to work at the same speed, and continues on his overtime, he will quickly become so over-fatigued that he will have to take a rest from work in order to recuperate. As a matter of fact, he generally begins to slack off to some extent directly overtime hours are worked, and he *must* do this if he is to last out at all. Also comparatively few workers are in the habit of utilizing every fraction of their available energy over their work, but they keep 1 or 2 units of energy in reserve even in war-time, and this reserve they can draw upon for overtime purposes

when necessary. Still, it remains evident that the thoroughly conscientious and hard-working munition worker cannot as a rule do any overtime work at all, except under wasteful and unphysiological conditions. He may produce a small temporary increase of output, but his total output, over a period of several weeks, is reduced rather than increased; or again, he can produce a small increase of output for a few days before a holiday, as he knows that he will be able to recover his full vigour again during the period of rest from work.

Limitation of Output.—In all of the operations referred to the workers were on a piece rate, or were paid so much per 100 articles produced. A piece-rate system is essential if one wishes to get the best results in repetition work. The work is of so dull and monotonous a character that if it were paid at a time rate the workers would inevitably relax their efforts as much as they could without incurring the resentment of the management. The importance of the piece-rate system is generally recognized, and it is adopted in some form or other in all of the munition factories with which I am acquainted, in such operations as lend themselves to it. However, I came across one operation in which two groups of workers, in different blocks of the same factory, were engaged on the same operation, one group being paid at a time rate and the other group at a piece rate. The operation consisted in sorting the brass cartridge cases of rifle ammunition, and picking out the buckled and abnormal cases. In a group of 18 women working for 25 weeks I found that in only 2 per cent of all the weekly outputs did the relative hourly output lie between 42 and 52: in 28 per cent of them it lay between 52 and 62, whilst the most frequent output of 62 to 72 occurred in 46 per cent of all cases. A better output

of 72 to 82 occurred in 21 per cent of the cases, and the best output of all, one of 82 to 92, in 3 per cent of the cases. That is to say, the best workers in their best weeks were able to achieve an hourly output just about double that of the worst workers in their worst weeks. I have found that a similar range of variation occurs in many other munition operations, such as

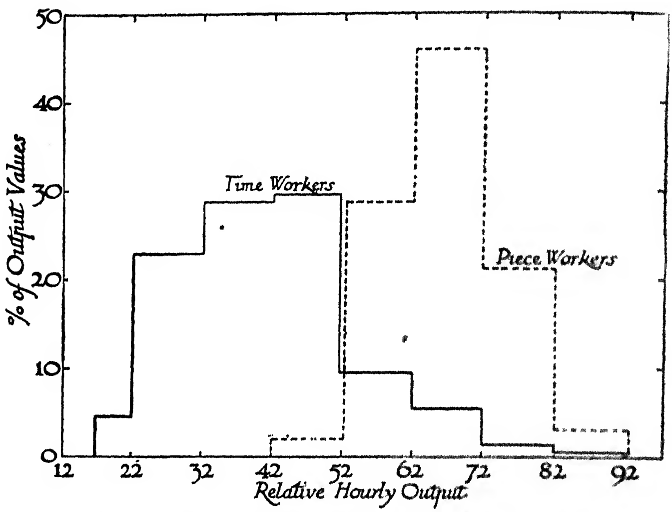


Fig. 3.—Variation in Output of Women sorting Cartridge Cases

turning fuse bodies, boring 3-inch shells, and in most cartridge-case operations. I have found, moreover, that the frequency of occurrence of the various output values follows the same lines as are roughly indicated in the curve shown on the right of fig. 3. The frequency varies according to the laws of probability, or the normal law of frequency of error. We find, for instance, that if we sort out a large group of individuals according to their stature, a small proportion

of these individuals are very short, a moderate proportion of them are rather short, a large proportion of them are of medium height, a moderate proportion of them are rather tall, and a small proportion of them are very tall. Similar frequencies of occurrence are observed for their muscular strength, for their keenness of eyesight, and for other physical attributes; and similar frequencies also for their capacity for producing munitions, supposing that they are all working their best. But supposing that the workers are artificially limiting their output, then the frequency of distribution of their output values would almost invariably fail to conform to the normal probability curve. Take, for instance, the other group of women who were sorting cartridges at a time rate. Their average output was only a third that of the piece-rate workers, but unfortunately the values are not directly comparable, as the type of sorting by the time-workers was rather more complex in character than that by the piece-workers. Assuming, for the sake of argument, that the best of the time-workers had as great an output as the best of the piece-workers (though we may be quite sure that they had no such thing), I found that their output values had the frequencies shown on the left side of fig. 3. A few of the women had an output of only 17 to 22, but the majority of them had an output of 32 to 52, or a lower value than that observed in any except 2 per cent of the piece-workers. In fact, the majority of the time-workers sorted cartridges only about half as fast as the majority of the piece-workers, though a few conscientious ones achieved a good output.

Other and much more important instances of limitation of output I have recently observed in one of the largest of our shipyards. In this yard, before the war, most of the workers were paid at a piece rate,

but they were likewise guaranteed a fixed time rate, so that however little work they did they were still paid a considerable wage. As long as there were plenty of shipyard hands available this system worked fairly well, for if a worker persistently slacked, so that he did not earn the guaranteed time rate, he could be discharged. During the war, however, the demand for shipyard hands, and especially for riveters, became greater than the available supply, and the men now controlled the situation. They soon learnt that it was easier and pleasanter to make no attempt to earn their piece rate, but to do as little work as possible, and still receive the very generous time rate which had been guaranteed them. At one period scarcely a riveter earned the money he was paid, and in some weeks they were paid nearly double as much wages as they had earned at current piece rates. When this system of a guaranteed time rate was abolished, the number of rivets per hour put in by the men was very nearly doubled. Taking three trial weeks in 1915, 1916, and 1918, the relative number of rivets per hour put in by each squad varied thus:—

	Nov., 1915.	Nov., 1916.	March, 1918.
Relative number of rivets ...	100 ...	185 ...	198

There is good reason for thinking that even now these riveters are by no means doing their best, but that they could attain a relative value of about 300 if they worked their hardest. As it is, they get such high wages, and have so little opportunity of spending them, that they lack the necessary incentive.

The other ironworkers in the yard, such as the platers, caulkers, and drillers, were not so bad as the riveters, but they limited their output likewise to some extent. So serious was the limitation at the worst period that it is probable that in the construction of

a single battleship considerably over £100,000 was paid for ironwork which was never done. This was sheer economic waste, for it was of no benefit to the riveters and others that they should idle away half their time. Rather was it to their moral detriment. Evidently, therefore, it is of the greatest importance that the workers should be induced to give us of their best, and entirely avoid any limitation of output. If necessary, let their hours of work be shortened, and their piece payments increased, but true industrial efficiency can never be attained unless artificial limitation of output is wholly abolished.

Lord Leverhulme's Scheme.—Lord Leverhulme has recently suggested the adoption of a six-hour working day. On his scheme one shift of workers starts at 7 a.m. and ceases work at 1.30 p.m., whilst there is a break of half an hour in the middle of the morning. A fresh shift of workers comes on at 1.30 and works till 8 p.m., with a half-hour's break for tea in the middle of the afternoon. By means of this double shift the machinery of the factory is kept running for 12 hours a day, or 72 hours a week, whereas on the usual 8-hours-a-day system it is running only 48 or 44 hours. The cost of machinery is such a considerable item compared with the cost of the human labour required to work it—sometimes, according to Lord Leverhulme, it is nine times as great—that by running the machinery all these extra hours a tremendous saving is effected in the total cost of production, and so it will be possible to pay the workers the same wages for a six-hours day as for an eight-hours day, and produce the articles as cheaply as before. As against this argument it must be remembered that many types of machinery have only a certain number of running hours, at the end of which they are worn out and must be replaced; so in some forms of industry

the saving of costs by running the machinery for 72 hours a week instead of 48 hours would not be considerable. Still, taking the industries as a whole, there would doubtless be a very great saving. When we come to compare the total output in a six-hour day with that in an eight-hour day it is clear, from the data previously quoted, that no hard-and-fast rule can be laid down. The workers engaged in vigorous and active work would probably produce nearly as much in six hours as in eight hours, but those who were passively watching automatic machines, or were engaged in other light work, would find it impossible to do so. Perhaps the difficulty might be solved in their case by arranging for them to work seven hours per day instead of six hours. They might start work at 6 a.m. instead of 7 a.m., whilst the second shift might work on till 9 p.m.

With Lord Leverhulme's contention that the workers ought to have two hours a day to devote to educational classes, or, later on, in the case of men, to military service, one has every sympathy. In consequence of their better education the workers would doubtless be able to work more skilfully and intelligently, and so the large amount of unskilled labour would gradually be abolished, and be replaced by more skilled labour, which could achieve a much greater production by the employment of more machinery. Still, the question is bound to be controlled to some extent by economic factors. If this country wishes to compete in the open markets of the world against other countries, such as Germany, which might be running two eight-hour shifts each day (e.g. 6 a.m. to 2 p.m., and 2 p.m. to 10 p.m.), it might be found impossible to grant the workers such considerable relaxation of hours. However, the question which should first be decided is: What number of hours, with work paid

at piece rates, gives the best output? Probably 8 hours a day or 44 hours a week (Saturday being a half-holiday) is a good average for most industries in peace-times; but if this is the best average it follows that 9 hours or more a day must be the best for some of the less active types of labour, and 6 or 7 hours for some of the more active ones. In any case, it is extremely important to get at the facts first, and then one can accurately predict the results of adopting a definite policy in one direction or another.

H. M. V.

FRESH AIR AND EFFICIENCY

The subject of physical efficiency makes an especially urgent claim upon our consideration in these momentous days of strife, and it will continue to do so during the strenuous period of peaceful effort that is to follow them; therefore it behoves us to practise and to promulgate those precepts that relate to our physical well-being. Foremost amongst these is the precept of fresh air. Indeed, the most striking lesson within the sphere of hygiene that our experience has to teach is the human need for fresh air, and how sensitively the human body reacts to the ceaseless play of its aerial environment. Designed as we were for open-air existence, is it surprising that artificial conditions which exclude a sufficiency of what the poet has called "Nature's sweet breath" should prove inimical to our physical efficiency and be attended by the Nemesis of much preventable sickness and premature death?

I propose, in the first place, to indicate briefly the nature of the past and present evidence of the evil consequences of the lack of fresh air upon health and physical and mental efficiency, and then to consider how foul air operates in producing these results—although the latter is a biological problem which has not yet been completely solved.

So far as the civil community is concerned, the evil consequences of the lack of fresh air are demonstrated by the following facts:—

1. There is evidence that it lowers resistance to acute disease (especially catarrhs, bronchitis, pneumonia, and phthisis) and that it favours chronic wasting diseases.

2. Dr. Ogles's researches demonstrated that of all the male industrial classes those with the lowest death-rates are the classes whose occupations are carried on in the open air. The death-rate from phthisis and diseases of the respiratory organs is greatly less among them than the rest of the male community; indeed, agricultural labourers furnish but half of the average adult male mortality from consumption! The differences in food and housing cannot possibly account for this much greater freedom from pulmonary disease.

3. The excessive incidence of pulmonary disease (exceeding 50 per cent) on the inmates of back-to-back houses, in which there can be no through-ventilation and useful circulation of air, has been well established by Tatham and others. Dr. Tatham's investigations at Salford were very thorough and exact. He found that in districts where *all* the houses were built on the vicious system known as "back-to-back", the phthisis death-rate was 5.2 per 1000 living; where 56 per cent of the houses were so built, the rate was 3.6; where 23 per cent only were so constructed, it was further reduced to 3.3; and, lastly, where there were *no* "back-to-back" houses—that is to say, where all the houses were provided with some means of light and air both in front and to the rear—the rate was only 2.8 per 1000. These results are all the more remarkable because, with the exception of the absence of means for through-ventilation, the back-to-back houses on the whole were, in Dr. Tatham's opinion, in better sanitary condition than the other houses.

4. During the past half-century there has been a

reduction of 50 per cent in the death-rate from phthisis in the civil community. Many factors have combined to bring about this remarkable result, but it is agreed on all sides that better housing (connoting better air conditions) have been an important factor.

There is some testimony to the fact that fresh air by day does not suffice to make amends for foul air by night—that the death-rate from respiratory diseases (including consumption) may be high amongst those placed under the best day conditions if the night conditions are bad (e.g. navy).

As a condition favouring the incidence of communicable disease, "overcrowding" operates in two directions: (*a*) the bad state of the atmosphere lowers resistance to infection; (*b*) the close juxtaposition of individuals favours the transference of infection. But "overcrowding" in the civil population is associated with poverty and its attendant lack of proper food, clothing, &c.; and so the consequences of overcrowding, *per se*, must be studied in populations from which we can disassociate the effects of poverty. The army and the navy furnish us with such populations.

Now what has the experience of our *army* to teach us?

A Royal Commission, appointed in 1857 to report upon the sanitary condition and improvement of army barracks and hospitals, reported (in 1861) that, of 76,000 men in barracks, 45 per cent had less than 400 cubic feet of space per man, and some 1300 had no more than 250. Now the higher cubic space has little value apart from the fact that with an increased allowance the problem of ventilation becomes simplified; but the Commissioners further found that, in respect of 56 per cent of the men, "no means of ventilation were provided", and for 44 per cent it was "imperfect and insufficient". It is pointed out in the 1861 report

that "the polluted atmospheres of overcrowded unventilated barrack rooms has been, in times past, a potent cause of disease and mortality in the British army", . . . that "the importance of this, as bearing upon the efficiency of the army, appears to have been hitherto very imperfectly appreciated", and that "stagnant air, especially in sleeping-rooms, is a poison". They recommended that 600 cubic feet per man should be provided as soon as practicable, and that arrangements should be made to renew the air within this space at least twice in every hour. But this minimum of 1200 cubic feet of fresh air per man per hour is insufficient. It would lead to 0.06 per cent of respiratory carbon dioxide in the atmosphere, and the air would then get too hot and moist; and so a minimum of 1200 cubic feet has long since been discarded.

If the soldier's air ration was so disgracefully small in 1861, it was doubtlesss rather worse than better prior to that period; for a previous Royal Commission on the sanitary state of the army had also recommended 600 cubic feet of space per man, and that circumstance is likely to have had some effect in increasing the space allotted to the soldier shortly before 1861.

It is certain that from 1861 there was a steadily-progressing improvement in the provision of cubic space and ventilation in barrack rooms, and that by 1869 there was little, if any, accommodation under 500 cubic feet per man; but the 600 cubic feet limit was by no means general—it became so a few years afterwards.

Now the best available indication we have of the effects of foul air upon human beings is provided by diseases of the lungs, and notably by consumption; but I should be disposed to select the non-fatal con-

dition generally described as "catarrh", as the most sensitive index, if the facts of its prevalence were available. This is, of course, not the case, and so we must take consumption and see whether the facts of its prevalence and of the mortality it caused in the British army on home service (as disclosed in the reports of the medical department on the health of the army) bear any relationship to the soldier's fresh-air ration. Unfortunately, in the earlier years to which I shall refer, there were changes in the nomenclature of the diseases of the respiratory tract which make a strict comparison with later years impossible; but, allowing for this, the following conclusions are amply justified by the statistical records:—Certainly from 1818 to 1846 there was but a very slight decrease in the mortality from diseases of the lungs; from 1850 to 1860 a decrease was rather more evident; but from 1860 to 1869 an enormous decline took place. Yet from 1866 to 1869 the admissions to hospitals from phthisis and hæmoptysis in the home army still slightly exceeded 10 per 1000, but from 1900 to 1910 such admissions had fallen 62 per cent; and in 1880 the consumption death-rate of the army was 75 per cent less than the pre-Crimean rate. This was "mainly the result of the improved condition of ventilation in the soldier's sleeping-rooms, which had been gradually effected since 1858" (De Chaumont, 1883). In the 'sixties the death-rate from consumption in the army was over 30 per cent higher than among male civilians of army age; while in recent years it has dropped considerably below the civilian rate.

Of course this striking reduction of consumption in the home army cannot be wholly ascribed to improved air conditions in barrack rooms; for during the long period under review certain improvements in clothing and feeding were introduced, and the earlier recog-

nition of consumption and improved precautions against its spread played a part. On the other hand, it may be argued that the air conditions of the worst barracks would have furnished a more evil record were it not for the fact that the men occupied, in rotation, barrack rooms with diversities of cubic space and ventilation.

In 1875 Dr. Farr found that the death-rate in the London garrison of the Guards was 20.4 per 1000 of strength. The rate was not more than 3 per 1000 just before the war. The fact that in the same barracks the men are now better spaced and the rooms better ventilated is known to have contributed largely to these happy results. Hear what the great Edmund Parkes (a man whom all hygienists hold in the greatest reverence) has to say in this connection:—

"With very different duties, a variable amount of syphilis, and altered diet, a great amount of phthisis has prevailed in the most varied stations of the army, and in the most beautiful climates: in Gibraltar, Malta, Ionia, Jamaica, Trinidad, Bermuda, &c., in all which places the only common condition was the vitiated atmosphere which our barrack system everywhere produced. And, as if to clench the argument, there has been of late years a most decided decline of phthisical cases in these stations, while the only circumstance which has notably changed in the time has been the condition of the air."

The experience of the *navy* is very similar to that of the army, although it is less accentuated. The invaliding rate from consumption during 1900 to 1910 shows in comparison with that of 1860 to 1870 a drop of 18 per cent. This is ascribed to the better spacing and placing of cabins, and the better ventilation provided since the early 'seventies. Prior to 1870, diseases of the respiratory organs were the most prolific source

of sickness and loss of efficiency in the navy (one-sixth of the total sickness, and one-fifth of the total deaths were ascribed to these diseases); whereas the average for the five years ending 1912 is between one-seventh and one-eighth of the total sickness, and but one-twentieth of the total deaths (after making full allowance for the men who are "invalided out" of the navy on account of these diseases).

As to our prisons, Baly, writing in 1868, recorded that consumption was three times more prevalent in Millbank Prison than in the Metropolis; and it is certain that more cubic space and better ventilation were the main factors in bringing about the subsequent great reduction in this disease among prisoners.

And what is there to be said of our army that is shaping so magnificently in the great war? It has been a wonderfully healthy army, and no effort has been spared to make and keep it so. I have, however, been greatly impressed, as the result of my inspections and the facts disclosed to me by medical officers, with the evidence this army has afforded of the value of ventilation in reducing "invaliding"; and I have reached the conviction that the sufficient ventilation of barracks, huts, and billets is a *prime* requirement of army sanitation in the interest of army efficiency. Realizing this, the Army Council, quite early in the war, issued an order that at least two diagonally opposite windows in every hut and barrack room were to be kept constantly open to their fullest extent (day and night); and the importance of sufficient ventilation was (later) again impressed upon the commands. In certain night inspections in winter months I found that the prevalence of conditions of catarrh amongst the occupants of huts bore a close relationship to the state of the atmosphere of the huts which were inspected. Units were found to vary considerably in the extent to

which they ventilated their huts. It was a usual experience (in the early days of the war) to find several of the men of a fully-occupied hut, in which all the windows were closed, to be coughing and sneezing; but when, at the same time and in the same large camp, there was another unit trained to more open-air conditions, with several open windows to each hut, there was generally an entire absence of those symptoms. There was a freshness in the atmosphere of these latter huts that contrasted pleasantly with the stuffy state of the air in the other huts inspected. This was very impressive evidence of the close relationship between fresh air and efficiency in the army—for catarrhal conditions not only lower the efficiency of the men who are able to carry on, they prevent a certain number from doing so; and, by conferring a predisposition, they are frequently the precursors of serious invaliding from other diseases. These catarrhal conditions lower resistance to several forms of disease, and have been intimately associated with the incidence of spotted fever and pneumonia among our troops. One cannot but be struck by the general coincidence of the prevalence of spotted fever with a high sick-rate from catarrhal affections. Furthermore, histories of outbreaks of spotted fever and pneumonia in civil communities usually disclose an association with over-crowding and lack of ventilation. And so it would appear that, whenever catarrhal conditions are unduly prevalent amongst our soldiers, it is wise to let this fact serve as a signal for increased ventilation, to treat it as raising the possibility of the presence or early appearance of more serious disease.

In the army hut the authorized mobilization scale of floor space per man is only 40 square feet; therefore, when it is fully occupied, it is necessarily very crowded, and unless the air is frequently renewed it soon be-

comes unhealthy. Any practicable increase in the floor space would be, *per se*, no material remedy for the bad air conditions. For with an additional 10 square feet of floor area the air would reach the same standard of impurity after a further few minutes; and if the air is only changed once in every hour the respiratory carbon dioxide would reach 0.13 per cent at the end of the hour, and the associated physical conditions would render the air unhealthy. Therefore, short of an impossible allowance of sleeping space, frequent air-renewal is the sole means of keeping the air fairly fresh, and therefore capable of maintaining health and vigour. For this, opposite open windows, as many as possible, according to weather conditions (and always at least two diagonally opposite ones), are necessary. If there are hopper windows, every other one on both sides should be permanently fixed in an open position. These remarks apply whatever other ventilation expedients have also been adopted. But, notwithstanding the fear of punishment for disobedience, orders are always most effective, from the standpoint of results, when all concerned are informed upon their object and importance; and the practice of the open window depends very largely indeed upon the formation of the conviction that leads to practice, and thus to the formation of habit. And so this subject has generally been introduced among those on which the soldier has been appealed to by the medical officer.

Unfortunately, efforts to promote the better ventilation of quarters by night have been seriously interfered with in many camps by the lighting orders necessitated by enemy bombing raids; for the darkening of an open window by closely covering it with a heavy curtain, &c., seriously discounts its value for ventilating purposes.

But I must not close this reference to army experiences without referring to a recent experience in the American army. In December, 1916 (as recorded in *The Military Surgeon*), a division of the United States army was under canvas in Camp Wilson, Texas. The great prevalence of respiratory diseases led to a conference of medical officers, at which it was agreed that better ventilation and airing of the tents was indicated. The co-operation of regimental commanders varied, and the prevalence of respiratory diseases, and of measles, closely conformed to these variations. Although nearly 14,000 men were occupying the same camp during the same period of observation, some units had a high sick-rate from respiratory diseases and measles, and others a low rate, and ventilation was found, after a close and skilled enquiry, to have a similar effect upon measles incidence as it had upon respiratory diseases, namely, it reduced both. It was also found that cold weather and rain favoured respiratory diseases among the troops by causing them to herd together in the huts. It is the stoves which attract the men, and these lead to an increased draught from any open window, and so this gets closed.

A very fatal disease which we in this country have had opportunities of bringing under proper scientific investigation only in quite recent years is cerebro-spinal fever or "spotted fever". The testimony to the value of fresh air in the prevention of this disease is very striking, and when spotted fever occurs we have learnt *from experience* the value of better spacing out and more fresh air in reducing its spread. The value of better ventilation in cerebro-spinal fever is partly due to the cooler air thereby secured, for the specific germ dies so rapidly in cool air that the chance of the spread of infection is thus reduced, but the fresher air probably acts chiefly by "keying

up" the individual's resistance. Overcrowding facilitates the transmission of the disease from man to man, and Captain J. A. Glover, R.A.M.C., and others, have established the fact that the "carrier-rate" of this disease increases with overcrowding.

The prime importance of ample space and the free ventilation of quarters as a preventive measure against spotted fever is emphasized in a special War Office memorandum. Doubtless when this disease is in evidence, and the carrier-rate is high, the beds should be kept *at least* $2\frac{1}{2}$ feet apart (involving a maximum of twenty-four men to the standard hut of 60 feet × 20 feet), and the freest possible ventilation should be provided.

It is interesting in this connection to note that the men in bell-tents, in which they are much more crowded than in huts, show no increased incidence of attack; indeed, although on the average the men in such tents have less than half of the mobilization scale of floor area in huts, the incidence of spotted fever, as also the carrier-rate, are generally *lower* with them. In my opinion this case is best explained by the fact that the air in the tents is relatively cooler.

There can be no doubt that a main factor determining the prevalence of consumption is foul air. The evidence as to this is overwhelming, and admits of no questioning, and the good results of the open-air treatment of the disease afford some corroborative testimony to this. The results obtained from the treatment of many other forms of disease (including infectious disease) on similar open-air lines is also very striking.

Seventy-five years ago Dr. Bodington treated his consumptive patients upon "open-air" lines. But even one hundred and fifty years ago Lind, a distinguished naval surgeon, advocated the best "open-

air" hospital conditions, and he gives evidence of how much better his patients did in old drafty tents than in crowded hospital wards. At the same time Brocklesby, an army surgeon, furnished similar testimony. Notwithstanding the cold and dampness of old sheds in which the soldiers were placed, he states that remarkably fewer died from the same disease, though under the same regimen and treated in the same manner, than was the case with those in hospital wards, and that the convalescents recovered sooner than those in the warmer and more weather-proof huts.

There is a mass of evidence to justify the conclusion that a lack of fresh air exerts a markedly deteriorating effect upon both mental and physical powers. But before indicating the nature and extent of the observations and experiments which constitute this evidence, it will conduce to a clearer understanding of the issues if I endeavour first to *explain* the close relationship of foul air to disease and loss of efficiency.

The research of recent years has done much to elucidate this biological problem, but the limitations of time do not permit me to do more than summarize this research. In this matter we have slowly felt our way to a scientific objective—hypotheses, based on imperfect knowledge, have been framed from time to time to explain the observed facts, and these have been tested in the light of an improving knowledge, and discarded to make place for the recent real advance of our knowledge on this subject. For this advance we are mainly indebted to the work, within recent years, of Haldane, Flügge, Leonard Hill, and certain American experimentalists.

The harmful effects of stuffy air were first ascribed to a form of poisoning, due either to the altered gaseous constituents of the air or to the presence of

exhaled organic matter of human origin, but singly and collectively they failed under the ordeal of experimentation to justify this contention, and as our knowledge of physiology increased they became more and more in conflict with its findings.

As to CO_2.—When human beings foul an atmosphere by respiration they add CO_2, a trace of organic matter, and a variable amount of odour, and they reduce the oxygen content. As to CO_2, even under the worst conditions of human fouling, this inert gas does not exceed 0.8 per cent of the atmosphere—it seldom exceeds 0.4 per cent—and experimentally we find that the *only* result from breathing air with even 1 per cent of CO_2 is a very faint increase in the depth of breathing (the slight rise in the CO_2 of the blood decreasing its alkalinity and so exciting the respiratory centre); and we know that in the small air sacs of the lungs the CO_2 is from 5 to 6 per cent. And yet until comparatively recently it was believed that it was the CO_2 added to the air by human respiration that was the responsible factor in the evil effects of foul air.

As to Oxygen.—The oxygen content of the most crowded and worst ventilated room is never 1 per cent below its amount in the outside air, and therefore it is always higher than it is in the Alpine health resorts; and the oxygen content of the air in the pulmonary air sacs is quite 20 per cent below that in the external air. The hypotheses of a volatile *poison* or of a toxic protein (or "crowd poison") in the trace of organic matter in expired air both lack experimental confirmation.

As to Odour.—In ordinary respiration the expired air is free from suspended matter, and sterile; and the odour of "stuffiness" in a crowded room is derived from albuminous decomposition products derived from buccal, nasal, and cutaneous surfaces, and

clothing. This odour can but have a transient psychic effect upon those who *first enter* an already stuffy room — for our very keen sense of odour is rapidly exhausted.

Certain other changes in fouled air had, until comparatively recently, received but little consideration. I refer to the fact that air markedly fouled by human occupation of a room becomes changed in its *physical* characters; it is more or less stagnant, its humidity is high, and its temperature considerably increased. Experimentation was therefore directed to test the power of the altered physical state of the atmosphere to produce the enervating effects of overcrowded and badly ventilated rooms. The experiments have generally consisted in confining men in comparatively small experimental chambers and observing the effects; and, later, certain contrivances were adopted for varying the quality and the quantity of the air within the chamber. Sometimes tubes leading from the chamber to the outside air have been provided, and it was found that when subjects were affected by the atmosphere of the chamber they obtained no relief by breathing through this tube, whereas if they stepped outside of the chamber relief came at once. Again, if a subject breathes through a tube the stale hot air of the chamber, while standing outside of it, no unpleasant symptoms appear. Even when sitting in the chamber relief is experienced when the air is set in motion by fans. These experiments have been repeated, with slight modifications, by several independent workers, and the results have always been in strict conformity. They establish the fact that the evil results of close, ill-ventilated rooms are not due to respiratory impurities accumulating in the frequently re-breathed air, but to its altered physical characters —in short, *the evils of foul air are not due to chemical*

impurities acting through the lungs, but to physical changes which act through the skin.

In order to explain the effects of this altered physical state of the atmosphere upon human beings it is necessary to recall a few physiological and physical facts. The heat-regulating mechanism of the human body is a provision of essential importance to health and life, and slight disturbances of it may produce marked effects. If the equilibrium between our heat production and our heat loss is disturbed, heat retention may ensue and symptoms develop that are closely akin to those brought about by foul-air conditions; and it is in a high degree probable that foul air acts by inducing heat retention, which is responsible for chemical changes in the tissues resulting in toxins which produce headache, fatigue, &c. Indeed, a vicious circle is established, for heat retention itself causes a rise in temperature, and this increases oxidation processes which lead to the production of more heat.

How does foul air induce heat retention? When a human being sits in a warm room with a still atmosphere he parts with heat to keep his body cool mainly by the evaporation of moisture through the sweat glands of his skin; for then there is relatively little loss of heat by radiation, convection, and conduction. In evaporation heat is rendered latent, and the necessary heat is abstracted from his body surface, and thus nature has provided a powerful means of *rapidly* cooling the body and of so maintaining the body temperature at the normal at exposures to very high temperatures, such as those of the hottest rooms of Turkish baths. But it is obvious that this evaporation which helps us to cope with the excessive heat production from within and heat reception from without, cannot operate properly if the air has little or no

"drying power", or capacity for taking up moisture, by reason of the fact that it is already nearly saturated. And so, while the temperature of the vitiated air rises, the chief means of cooling the body is thrown out of action by the concomitant increase in the moisture of the atmosphere, and slight heat retention takes place, with symptoms of inattention, listlessness, restlessness, poor work, and headache. Thus, in a hot room, more blood is sent to the skin for heat-regulating purposes, and the activity of the countless sweat glands is increased; but if the heat loss is interfered with, as it is in a crowded ill-ventilated room, along with a lowered blood pressure there is an accelerated pulse beat, and the whole metabolism of the body is affected by the heat retention, and if work is done it is performed under handicapping bodily circumstance.

The distaste for physical labour upon a hot, humid day has a deeper basis than mere disinclination—the muscles are physically incapable of performing their best work. The effect of the accumulation of fatigue products, acting toxically in reducing the activity of the tissues, is increased by the raised body temperature. The effect of moist heat upon the muscular power has been tested and gauged by several workers. Lee and Scott found in respect to cats exposed for six hours to atmospheric conditions varying only in respect to the temperature and humidity, that muscles removed immediately after such exposure, and stimulated to exhaustion, showed a progressive decrease in the average duration of their working power and of the amount of work performed, as the temperature and humidity of the air were raised from 70° F. and 5.2 per cent respectively, to 91° F. and 90 per cent. It has also been found (Patrizi) that human muscles, when heated by localized hot baths, are subject to early fatigue and exhaustion.

I have referred to the fact that the chamber experiments proved that relief is experienced when the air of the chamber is set in motion by fans. Doubtless this relief, even when the foul air has a wet-bulb temperature of 80°–85° F., results from the displacement it brings about of the hot air, at a wet-bulb temperature of 98° F., which is in contact with the skin and enmeshed in the clothing immediately against the skin.

In 1906 Dr. James Kerr reported to the London County Council (as the Education Authority for the County of London) upon the relation of the class-room atmosphere to the working efficiency of school children. The following tests were adopted: The number of simple addition and subtraction sums that could be worked in five minutes; and, in order to assess correct judgment, the estimation of an angle copied from a blackboard. Numerous observations were made by Drs. Thomas, Stevenson, Hogarth, and Brincker in which the four chief air factors, viz. temperature, humidity, movement of air, and carbon dioxide, were associated in every combination and their effects studied. It was found that "in every case where boys were working under good air conditions the results showed a distinct improvement at the end of the session, whereas when these air conditions were acknowledged to be bad, the results were always inferior at the end of the session". Again, "if the results of similar mental tests set before and after a school session to a class of average children show a falling-off, or even an absence of improvement, in mental alertness and accuracy, it is just to conclude that some deteriorating influence has been at work. By methods of exclusion this was shown, in these observations, to be the atmospheric conditions". The observations appeared to warrant the following further

conclusions: That carbon dioxide up to 0.35 per cent exerts no appreciable effect on mental capacity; that temperatures above 65° F., independent of other air conditions, give rise to definite subjective symptoms (slackness and inattention in some, headache in others, and deterioration in mental work); that these symptoms do not appear at 65° F. if the air is kept in gentle movement by a fan in the room, and that at higher temperatures the above symptoms are ameliorated by such movements of the air; that with temperatures of 70° F. and over, other factors being normal, there are marked symptoms and very evident deterioration in mental alertness and accuracy; and that relative humidity does not affect the mental capacity of children at low temperatures (below 65° F.), but an increase of humidity appears to aggravate the effects of higher temperatures in reducing working capacity. Observations in America (Boston) confirm certain particulars of these findings.

The New York State Commission on Ventilation has recently conducted experiments which, in the first place, have been directed towards ascertaining the effects of high temperature. The physical tests selected were (*a*) the number of times a dumb-bell could be raised to a given height, and (*b*) the work registered by a Krogh bicycle ergometer (a standard bicycle with an artificial resistance). The mental tests consisted of (*a*) the naming of colours, (*b*) the cancellation of given letters in a large group, and (*c*) the addition of numbers, mental arithmetic, and type-writing.

The results of these experiments indicate that overheated rooms are not only uncomfortable, they also produce well-marked effects on the heat-regulating mechanism and circulatory system, and materially reduce the *inclination* (though not the *power*) for

physical work; and that the chemical state of the air (even when the CO_2 exceeds 0.3 per cent) has no such effect. Even a slightly elevated room temperature (of 75° F.) gave results which warrant careful precautions against overheating. In a room of 75° F. about 15 per cent less physical work was done than when the same students were tested at 68° F.; and at 86° F. the physical work done fell 35 per cent. High temperature had no effect upon the *quality* of mental work, save in reducing the inclination for it. Furthermore, by means of standard lunches and an estimate of the calories consumed, it was found that the food consumption was 9 per cent greater in a well-ventilated atmosphere than in foul air. The value of open-air schools as promoting the physical welfare of children has long been recognized. The constant benefits from such schools include increases in the weight, strength, chest expansion, hæmoglobin content of the blood, and physical activity, with a greater need of food and increased powers of assimilation. "The pupils learn with less effort, better retain the information imparted, and show less and less of the nervous strain due to close, heated schoolrooms" (Board of Health, Michigan). These results are universally believed to be mainly due to improved air conditions, and incidentally it may be added that the children require better conditions for body heat removal than adults; but the better clothing of the body, the better dieting, the midday sleep, and the reduction in mental work, are all contributing factors to the good results obtained. The circumstance that, despite the lightening of the mental work, the scholars do not fall behind the other children in their schooling is noteworthy.

It may be claimed that experiments have now established the facts that if the surrounding temperature exceeds 70° F. (W.B.) it is liable to produce discom-

fort and to lower physical and mental efficiency; that such symptoms set in when the body temperature rises above 99° F.; that continuous work is impossible with a W.B.T. of 78° F.; and that 2000 cubic feet of air per head per hour at about 60° F. are generally required to regulate suitably the physical state of the atmosphere of occupied rooms. Although the amount of respiratory CO_2 in the air (within a likely degree of "overcrowding") does not matter, it remains a useful *index* to bad air conditions; for although a low figure of respiratory CO_2 does not, *per se*, guarantee a satisfactory atmosphere, the harmful physical changes increase pretty much *pari passu* with the respiratory CO_2. If, then, we allow an adult 2000 cubic feet of fresh air per hour, this will keep down the CO_2 respiratory impurity to 0.036 per cent, and it will keep the temperature and humidity within hygienic limits. Even in the winter months an individual can readily train himself to tolerate an air movement that will change the air in the room two and a half times per hour, and so 800 cubic feet of space will suffice for one adult; but if he can secure 1000 cubic feet, the air need be changed only twice in every hour.

How do foul air conditions operate in favouring actual disease? Let us first consider communicable disease. It is certain that the depressing effect of foul air reduces our resistance to many forms of infection, and so increases the susceptible portion of the community. Catarrh is the cause of much inefficiency. It is fostered by foul air conditions, and the subsequent chilling to which they expose us; and, like influenza, measles, diphtheria, spotted fever, consumption, &c., it is often spread to susceptible persons in the immediate vicinity by infection organisms, in particles of moisture discharged from a sufferer in the acts of coughing, sneezing, and forcible speak-

ing. Muller and Nattie found that the infection of rabbits with "snuffles" (*B. bovis septicus*) is favoured by chilling the animals after they had been exposed to heat. Moreover, Leonard Hill has drawn attention to the fact that a hot atmosphere, especially when the humidity is high, leads to a congestion of the mucous membrane of the nose, and that the increased secretion of tissue lymph that results may provide an abnormally favourable nidus for the development of germs of disease.

As to non-communicable diseases of the respiratory organs, here again the depressing effects of foul air and chilling reduce resistance to the effect upon the lungs of any sudden transition from the overheated moist atmosphere of a stuffy room to the outside air of the colder months. Bronchitis may result, and attacks of frequent recurrence lead to lung conditions which claim a heavy toll upon health and life. The frequency with which such lung conditions are followed by consumption is testimony to the fact that they greatly favour the invasion of that disease.

Thus the most essential requirement of our aerial environment is that it should permit an easy loss of heat from our bodies. The best indication of the rate at which the skin surface can part with heat is obtained by Leonard Hill's "Kata-thermometer". Essentially this instrument is a large-bulb spirit thermometer, the bulb of which may be surrounded by a muslin cover. This thermometer is first placed in hot water (about 150° F.), the excess of water is jerked off, and the Kata-thermometer is then suspended in the atmosphere, and the number of seconds taken in cooling from 100° F. to 95° F. is noted. This indicates the rate of cooling due to radiation, convection, and evaporation. The rate of cooling at body temperature is obtained by means of a factor for each instrument,

and it is expressed in terms of mille-calories per square centimetre per second. The wet Kata-thermometer result will be at least 20 (it may reach 28 out-of-doors) if the air is in a satisfactory state.

This rate of loss of body heat by conduction and convection is promoted by the movement of air past the body—more especially, of course, when the moving air is cool. Fresh air refreshes by its rapid removal of heat from the body; and *the prime requirement of ventilation is to keep the air relatively cool and in gentle motion.* The problem is one of maintaining air-freshness rather than air-*purity*; for the beneficial results of fresh air are chiefly on the surface of the body and not on the lungs. The bracing effect of the ceaseless flow of sensory impressions resulting from the movement of cool air over the skin is also of high value in promoting our efficiency; we live on a higher plane, and all our vital functions are "toned up". Thus fresh air promotes the vigorous tone of the nervous system; favours the circulation and the best distribution of the blood in the system; more oxygen and food are taken in, and metabolism is increased; it tones up the system and makes us more vigorous of brain and muscle; while warm, foul air relaxes and enervates, and lowers our efficiency. It is not surprising, therefore, that the sedentary worker in unduly warm and insufficiently ventilated offices, work-rooms, and sitting-rooms suffers a loss in bodily and mental vigour. It is the penalty that he pays for his neglect of fresh air and exercise.

We must fight against the tendency to "coddle", to acquire that evil and unnatural hyper-sensitiveness to cool air which is so much in evidence. By accustoming ourselves to slight draughts, which are inseparable from fresh-air conditions, we reduce the risks from chills. This toleration can only be

achieved by maintaining the atmosphere on the cool (fresh) side, and thus reducing the difference in temperatures between the internal and external air.

A draught is the perception of a current of cool air on a warm skin. The human organism, as we have seen, makes certain dispositions in order to face the heat and the cold. It is impossible to maintain at one and the same time such dispositions both for heat and cold, and to a body set for warmth any relatively cold air movement may begin by causing discomfort and end by chill—a prolonged setting of the body for cold, by which the cutaneous blood-vessels are contracted and the blood driven from the skin to the internal organs, and so congesting them.

Whilst the evil effects of foul air admit of no questioning, and the importance of fresh air is a lesson which has been shouted to us through the centuries, yet our stuffy living and sleeping rooms and workshops still claim a heavy toll of human health, happiness, and efficiency. It is indisputably true to state that improved air conditions are the best proved, the most scientific, the cheapest, and the most generally available of all the means for administering to our efficiency.

In conclusion, the measures for ensuring success in acquiring and maintaining the fresh-air regime of life may be summarized:—

1. The prime requirement is a fixed resolve to succeed.

2. The summer-time is the season in which to start the training for the fresh-air habit, and it is surprising how soon toleration sets in.

3. This toleration is promoted by baring the body for ten minutes before getting into bed overnight and after getting out in the morning, and then performing some exercises or rough towelling.

4. A window (or windows) must be opened day and night in every occupied room. If weather conditions limit the application of this rule, the door should be kept wide open. The fireplace and chimney opening must never be blocked.

5. To aid the toleration of cold fresh air (and in windy and wet weather) certain simple contrivances are useful. It is important that cold fresh air should enter a room in an upward direction, at a height which is above the heads of the seated occupants; it then in rising loses its initial velocity and falls as a gentle air cascade over our bodies. Hinckes-Bird's well-known device is to place a solid block of wood or glass under the entire length of the lower-sash frame of a window, which has the effect of raising the top rail of the lower sash above the bottom rail of the upper sash; and so, while excluding wind, rain, and snow, air is admitted between the two overlapping sashes in an upward direction. Or Venetian blinds, with the laths turned upwards, may be fixed over a partly open window. Or wire gauze on a frame is made to fit accurately an opening left by lowering the upper sash. Of course a hopper inlet window with side checks is far more efficient than the foregoing contrivances, and these should be general in all of the larger offices and work-rooms. Valvular openings into the chimney flue near to the ceiling (Arnott) constitute a simple and cheap provision, when a fire is burning, that usefully aids air renewal in fully occupied sitting-rooms.

6. Beds and chairs should not be placed in the line of main draughts—as between the windows and fire, or between windows and doors of rooms; or when it is difficult to avoid the direction of draughts, a screen may be used to shield the body. Such screens may be easily improvised.

7. The body must be warmly clad with light woollen

garments next to the skin. Especially is this important during the process of acclimatization.

8. Avoid overcrowding and overcrowded rooms.

9. If married, we must of necessity make converts of our wives or husbands. A woman's main objection to the open window sometimes arises from the fact that, in large towns especially, her clean white curtains so soon become dirty, and many husbands are not disposed to sacrifice comfort to health even for the short period necessary for the establishment of toleration. But no one can doubt that the extra household washing and some temporary discomfort are amply compensated for when acquainted with the facts that have been embodied in this brief presentation of the subject. The message of these facts is—The Open Window in the Cause of Efficiency and Health.

H. R. K.

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